THE AMERICAN MINERALOGIST
JOURNAL OF THE MINERALOGICAL SOCIETY OF AMERICA

Vol. 19 MAY, 1934 No. 5

PSEUDO-CATACLASTIC TEXTURE OF REPLACEMENT ORIGIN IN IGNEOUS ROCKS

GEORGE H. ANDERSON, *California Institute of Technology.*

Petrographers in recent years have tended to place increasing emphasis upon the importance of replacement processes in igneous rocks. The movement has received impetus from the study of pegmatites, especially by Brögger[1] and Fersman[2] in Europe and by Hess,[3] Landes[4] and Schaller[5] in the United States. These authors have presented convincing evidence for a replacement sequence in the development of these bodies. Other investigators have described instances in which large masses of plutonic rocks appear to have undergone important modifications in chemical and mineralogical composition since their consolidation.

Some authors indicate a belief that large bodies of granite may be wholly or in part of replacement origin. Grout,[6] for example, says:

---

[1] Brögger, W. C., Die Mineralien d. Syenitpegmatitgänge der Südnorwegischen Augit- und Nephelinsyenite: Allgemeiner Theil, *Zeitschr. Kryst.*, vol. **16,** 1890.

[2] Fersman, A. E., Ueber die Natur der Pegmatitbildungen: *Compt. Rend., Acad. Sci. Russie*, pp. 89–92, 1924.

Fersman, A. E., Ueber die geochemisch-genetisch Klassification der Granitpegmatite: *Tschermak's Min. Petr. Mitt.*, vol. **41,** pp. 64–83, 1931.

Fersman, A. E., Zur Geochemie der Granitpegmatite: *Tschermak's Min. Petr. Mitt.*, vol. **41,** pp. 200–213, 1931.

[3] Hess, F. L., The Natural History of Pegmatites: *Eng. and Min. Jour.*, vol. **120,** pp. 289–298, 1925.

[4] Landes, K. K., Paragenesis of Granite Pegmatites of Central Maine, *Am. Mineral.*, vol. **10,** pp. 355–411, 1925.

Landes, K. K., Baringer Hill, Texas, Pegmatite: *Am. Mineral.*, vol. **17,** pp. 381–391, 1932.

Landes, K. K., Origin and Classification of Pegmatites: *Am. Mineral.*, vol. **18,** pp. 33–56; 95–104, 1933.

[5] Schaller, W. T., The Genesis of Lithium Pegmatites: *Am. Jour. Sci.* (5), vol. **10,** pp. 269–279, 1925.

Schaller, W. T., Mineral Replacements in Pegmatites: *Am. Mineral.*, vol. **12,** pp. 59–63, 1927.

[6] Grout, Frank. F., *Petrography and Petrology*, New York, **1932,** p. 188.

> If a granite magma is intruded into massive quartzites and so disseminated that its channels of access are not visible, it may so largely replace the original as to form a rock indistinguishable from granite. Some intermediate stages in this series of replacement effects suggests that certain large masses of granite may be really results of replacement.[7]

The studies of Sederholm[8] on the pre-Cambrian granites of Finland convinced him that many of these bodies were formed *in situ* by the impregnation of leptites and other rocks of a sedimentary character with fluid emanations from a subjacent magma—a process certainly closely related to that of replacement.

That albitization, a replacement process, may furnish the key to the genesis of the alkaline rocks, is a suggestion advanced by Gillson,[9] a strong advocate of the importance of post-consolidation phenomena in igneous rocks. The suggestion derives support from the investigations of certain British petrographers[10] into the nature and origin of the rocks of the spilitic suite.

Gilluly[11] in a recent paper gives reasons for believing that bodies of albite granite several square miles in area in central Oregon have been formed by hydrothermal alteration of a biotite-quartz-diorite with which they are associated. Gilluly's findings are in accord with the views of Bowen[12] who favors an origin by replacement of all albite-rich rocks.

---

[7] See also: Quirke and Collins, The Disappearance of the Huronian: *Can. Geol. Surv.*, Mem. **160,** 1930.

[8] Sederholm, J. J., On Migmatites and Associated Pre-Cambrian Rocks of Southwest Finland, Parts I and II: *Bull. Com. Geol. de Finlande,* Nos. **58,** 1923, and **77,** 1929.

Sederholm, J. J., Ueber die Entstehung der migmatischen Gesteine: *Geol. Rundschau*, pp. 174–185, 1913.

Sederholm, J. J., Die regionale Umschmeltzung (Anatexis) erlautert an typischen Beispielen: *Compt. Rend. Congr. geol. internat. Stockholm*, pp. 573–586, 1910.

Sederholm, J. J., On Regional Granitization (or Anatexis): *Compt. Rend., XII, Congr. geol. internat. Canada*, pp. 319–324, **1913.**

[9] Gillson, J. L., Origin of Alkaline Rocks: *Jour. Geol.*, vol. **36,** pp. 471–474, 1928.

[10] Bailey, E. B., and Grabham, G. W., The Albitization of Basic Plagioclase Feldspars: *Geol. Mag.*, pp. 250–256, **1909.**

Dewey, H., and Flett, J. S., On Some British Pillow Lavas and the Rocks Associated with Them: *Geol. Mag.*, p. 209, **1911.**

Wells, A. K., Nomenclature of the Spilitic Suite: *Geol. Mag.*, **1923,** esp. Part II, pp. 62–74.

[11] Gilluly, James, Replacement Origin of the Albite Granite near Sparta, Oregon: *U. S. Geol. Surv., Prof. Paper* **175-C,** 1933.

[12] Bowen, N. L., Diabase and Granophyre of the Gowganda Lake District, Quebec: *Jour. Geol.*, vol. **18,** pp. 658–674, 1910.

Bowen, N. L., *The Evolution of the Igneous Rocks*, Princeton, **1928,** p. 132.

These illustrations could be multiplied many times without exhausting the list.[13] In spite of the generally recognized importance of replacement in petrogenesis, however, little attempt has been made to describe systematically textures which result from, or are characteristically associated with, this process. Textures of replacement origin have been the subject of much study in metalliferous ores, but in rocks they have almost escaped attention, although it is true that certain microstructures such as myrmekites, some types of perthites and occasionally even graphic structure in granites are coming to be regarded as being at least in part the products of metasomatism.

The writer has recently devoted much study to the rocks composing a granite batholith in the northern part of the Inyo-White Mountain range.[14] These rocks give evidence of having been profoundly modified by replacement processes at a time considerably after their consolidation. The changes thus produced include especially the albitization of the potash feldspars, the development of a number of new (post-consolidation) minerals such as sericite, chlorite, epidote and biotite, the introduction of large amounts of silica and the formation of a texture which it is the object of this paper to describe.

It is proposed to designate this texture by the term "pseudocataclastic texture" because of its close resemblance to true cataclastic texture. The latter, as is well-known, is a term used by petrographers in the description of rocks which have undergone dynamometamorphism. According to Johannsen[15] it was introduced by Kjerulf in 1855 and applies to a texture "characterized by crushed, fragmentary, deformed, and strained crystals." It is in part synonymous with "mortar-" and "mylonitic texture" but it is a broader term than either of these and includes both of them. In its original usage it does not appear to have extended to chemical changes or to effects produced by circulating solutions in the rock. Later writers have included various mineralogical changes involving recombinations of chemical units among the effects produced by dynamometamorphism, but, as Sederholm[16] has pointed out, many of these changes can probably take place only in the presence of fluid media. Strictly speaking they are not part of cataclastic texture, although in many cases it is possible that they may be considered to belong to intermediate stages between cataclastic and replacement textures[17] or to the combined effects of pressure and circulating solutions. "Cataclasis," says Sederholm,[18] "is in general a destructive process; it is not creating new minerals or rocks. The use of the term 'dynamometamorphism' for every metamorphic change which cannot otherwise be accounted for should be discontinued as not warranted by facts."

---

[13] The idea of granitization by replacement or assimilation (the French word is "digestion") appears to have originated with the French school of petrographers. One of the earliest discussions is contained in the memoir by A. Michel-Levy: Contribution a l'etude du granite de Flamanville et des granites français en general: *Bull. Carte geol. de France*, No. **36**, 1893.

[14] Anderson, G. H., Petrography of the North Half of the White Mountain Quadrangle of California-Nevada. Doctor's Dissertation, California Institute of Technology, **1933.**

[15] Johannsen, A., *A Descriptive Petrography of the Igneous Rocks*, I, **1931**, p. 200.

In a rock exhibiting cataclastic texture the primary mineral grains are commonly set in a finer-grained secondary matrix composed of fragments of the adjacent primary grains. The plagioclases will usually have bent or broken twinning lamellae and the quartz will ordinarily show undulatory extinction. The contacts between the older grains and the matrix may be involved but they are not such as would indicate a corrosive attack upon the former. The matrix has been produced principally by mechanical stress—crushing. It may make up a small part or the greater part of the rock, according to the degree of metamorphism.

Although the general picture in pseudo-cataclastic texture may in some cases be remarkably similar to the above, two significant differences are always to be observed. The first of these is in the relation of the matrix to the primary grains. This is invariably strongly suggestive of corrosion of the primary grains by solutions instrumental in depositing the matrix. The contacts are such as cannot conceivably have been formed by pressure alone.

The second important difference is the presence in abundance in rocks exhibiting pseudo-cataclastic texture of new minerals formed at least in part of materials brought in from a source outside the immediate field of observation. The grains of the matrix are not exclusively nor even chiefly mere fragments of the older

[16] Sederholm, J. J., On Migmatites and Associated Pre-Cambrian Rocks of Southwest Finland, Part II: *Bull. Com. Geol. de Finlande,* No. **77,** pp. 29, 128, 1929.

[17] Attention may be called to the views of Barrell, who held that recrystallization in schists and gneisses is largely the result of reaction with the emanations from subjacent batholiths. (Barrell, J., The Relation of Subjacent Igneous Invasion to Regional Metamorphism: *Amer. Jour. Sci.,* (5), vol. **I,** pp. 1–19; pp. 174–186; pp. 255–267. 1925.)

[18] Sederholm, J. J., *Op. cit.,* p. 128.

grains but are of independent, probably hydrothermal, origin. Commonly they include large amounts of quartz, sericite, chlorite, biotite and epidote. If these are also present as primary minerals they usually possess different optical properties in the two modes of occurrence. Myrmekite is nearly always to be observed in or fringing the matrix, especially where the latter borders potash feldspar. The primary grains are commonly much altered—microcline or orthoclase, for example, may be highly albitized and the plagioclase sericitized or saussuritized.

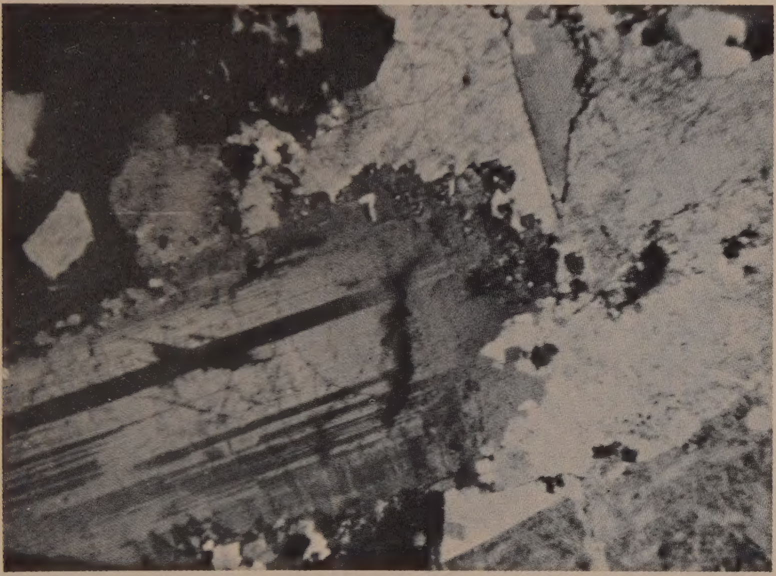

FIG. 1. The large grain of plagioclase extending diagonally downward to the left from the center of the field is readily recognized by its characteristic twinning. The light-colored grain forming most of the right half of the field is potash feldspar, considerably clouded by partial alteration to sodic feldspar. The grain at extinction in the upper left is also potash feldspar. The triangular-shaped grain above and to the right of the center is quartz.

Bordering the plagioclase grain is a fine-grained intergrowth of quartz, feldspar and chlorite closely resembling a trituration zone in a crushed rock. Its true origin by crystallization from replacing solutions is indicated, however, not only by the sinuosity of its contact with the plagioclase, which appears to have been corroded in the process but also by its continuity, more clearly shown upon rotation of the microscope stage, with the lace-like fringe of myrmekite at the end of the plagioclase grain. A similar replacement zone may be seen bordering the triangular-shaped quartz grain above the myrmekite. Crossed nicols, ×37.

In the White Mountains batholith pseudo-cataclastic texture appears to have followed an orderly course of development. In the earliest stage the secondary (matrix) material was confined to narrow, sinuous veins which for the most part followed the contacts between the older minerals. The latter were corroded by the vein-forming solutions. As corrosion proceeded the veins widened and the borders of the older minerals became frayed and ragged. Simultaneously new minerals were precipitated in the veins. The secondary material formed an ever-increasing proportion of the rock. With continuation of the process the vein-like aspect disappeared. In sections representing advanced stages there are only a few faint relicts[19] of the primary grains scattered through a fine-

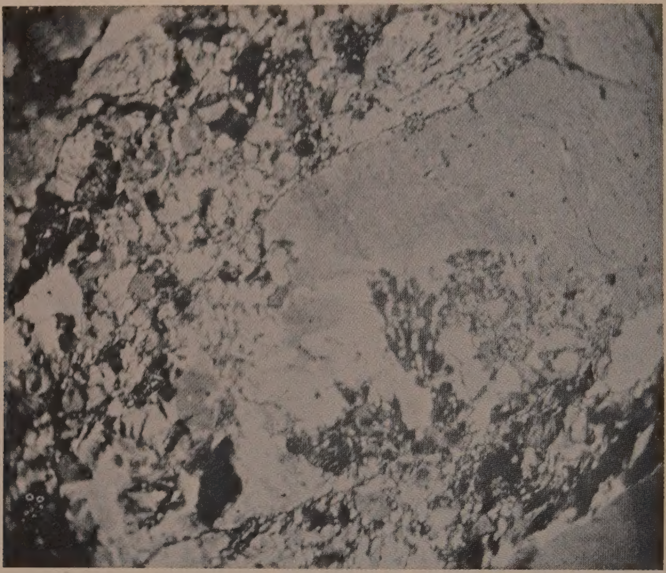

FIG. 2. The large gray grain with the ragged border extending diagonally upward to the right from the center of the view is potash feldspar. It is surrounded by a fine-grained intergrowth of quartz, feldspar, chlorite and epidote, fringed with myrmekite. The appearance of corrosion of the potash feldspar is too obvious to need comment. The light-colored splotchy border of the potash feldspar appears to have been produced by alteration by the corroding solutions. Crossed nicols, ×30.

---

[19] "Sick-looking" is a colloquial term which has been used to describe the appearance of these grains. It gives a better picture than any more elegant word that has been suggested.

grained secondary matrix. The entire rock has become to a large extent recrystallized and replaced.

It is a striking fact that the grains of the veins or matrix are seldom of the same minerals as the large (primary) grains in the immediate vicinity. For example, a vein passing between or crossing grains of microcline may contain quartz, albite, epidote and biotite with little or no potash feldspar. Frequently it is fringed with myrmekite. Commonly there is a definite arrangement of minerals in the veins or matrix suggestive of a paragenetic succession which is, however, not constant for the entire rock.

The veins of the earlier stages frequently coalesce to form larger and larger veins so that the pattern may approach arborescent or dendritic forms. This may often be observed within the area represented by a single large section. Conversely, a vein may become narrower and narrower until it finally dwindles to a rather indefinite termination.

Pseudo-cataclastic texture may develop in rocks which have previously been subjected to mechanical deformation. It is reasonable to suppose, indeed, that such rocks would offer an especially favorable opportunity for its development because of the greater ease with which the necessary solutions could gain entrance and circulate. Such instances have actually been observed locally in the White Mountains batholith. In these occurrences the effects of the earlier crushing are plainly evident in the rocks, but the fractures have been healed by minerals deposited from the later solutions.

On the other hand, pseudo-cataclastic texture is often well-developed where evidences of mechanical stress are absent. In such rocks the large primary grains exhibit no fractures, twinning lamellae in plagioclase are not bent or broken and even undulatory extinction in quartz, one of the first evidences of strain, is frequently not to be seen.

In numerous localities on the borders of the White Mountains batholith are bodies of quartz-hornblende diorite. Field evidence clearly indicates that these are early-solidified marginal phases of the main intrusive. Although pseudo-cataclastic texture is everywhere to be observed in some stage of development in the granites of the batholith, it is present only in minor degree in and is frequently completely absent from these early diorites. If the texture were the result simply of mechanical deformation it is reasonable to expect that it would be as clearly exhibited by the diorites as by the granites.

On the other hand, pseudo-cataclastic texture is a conspicuous feature of the aplites and the pegmatites which occur in the intrusive mass itself, and which cannot, therefore, have been formed until after the solidification of the outer parts of the batholith. Pegmatites, moreover, are commonly recognized as being formed of materials which represent the end-stage products of a crystallizing magma. The presence of pseudo-cataclastic texture in these bodies serves to demonstrate that it cannot have been produced by movements within the incompletely solidified mass.

The solutions which produced pseudo-cataclastic texture in the rocks of the White Mountains batholith must have been of very low viscosity. They probably operated under high temperatures and extremely high pressures which enabled them to take advantage of very minute channelways. These they enlarged and extended as they advanced.[20] Quantitative studies undertaken to determine accurately the chemical modifications produced in the rocks by their action are still incomplete, but microscopic observations and calculations clearly indicate that they carried into the rocks large quantities of sodium and silicon and probably also some magnesium and iron. The sodium in part replaced the potassium. in the potash feldspars and in part went to form second-generation albite in the secondary matrix. Contrary to the observations of Bailey and Grabham[21] on the spilites, however, the primary plagioclases are almost free from albitization. The evidence shows that under the conditions prevailing in the rocks at the time these changes occurred, albitization of the plagioclases—even of the more basic interior parts of the zoned crystals—could not take place so long as unaltered potash feldspar remained in the vicinity.

---

[20] If doubt exists as to the permeability of rocks to solutions of this sort, it should be dismissed. Much evidence has been accumulated by various investigators to show that under such conditions a high degree of permeability does actually exist. "Deuteric minerals," says Gillson (Gillson, J. L., The Granite of Conway N. H., *Am. Mineral.*, vol. **12,** p. 319, 1927) "illustrate, as do the widely disseminated minerals of contact metamorphic zones, the power of these igneous emanations to pervade solid rock without visible channel or fissure, a fact to which Kemp, for example, has already called attention." It should be remembered, moreover, that previously existing channels may have become sealed and rendered indistinguishable by the very solutions which took advantage of them.

[21] Bailey, E. B. and Grabham, G. W., *Op. cit.*

The potassium liberated from the microcline and orthoclase went into the formation of sericite in the secondary matrix or in the primary plagioclases, which are frequently highly sericitized. Some of the potassium in excess may have been lost from the rock. Calcium derived from the primary plagioclases united with iron to form epidote which is commonly present both in the plagioclases and in the secondary matrix. Iron and magnesium, undoubtedly derived in part from the original minerals of the rock but probably increased by additions from some outside source, entered into the formation of the biotite and chlorite commonly present in large quantity in the secondary matrix.

It is apparent, therefore, that conditions favored both the ready interchange of substances within the rock and the introduction of material from an outside source. These conditions were provided by freely-circulating fluid media. That the secondary matrix was formed by precipitation from these solutions is indicated by the presence in it of the same minerals which took part in or were formed as a result of the replacements; namely, albite, sericite, biotite, chlorite and epidote. Mineralogical changes of this type are among the most convincing indications of the true origin of the texture which is here described.

In conclusion, the writer wishes to acknowledge his indebtedness to Dr. Ian Campbell and Dr. Rene Engel of the Division of Geology and Paleontology of the California Institute of Technology for advice and suggestion in making the petrographic studies of which the results are in part presented in this paper, and to these gentlemen and to Professor F. L. Ransome for the critical reading of the manuscript.

CONTRIBUTIONS TO CRYSTALLOGRAPHY: CLAUDETITE; MINASRAGRITE; SAMSONITE; NATIVE SELENIUM; INDIUM

Charles Palache, *Harvard University.*

CLAUDETITE

Our knowledge of the crystal form of the oxide of arsenic, claudetite, rests chiefly on the study by Schmidt[1] of crystals formed as the result of a mine fire at Szomolnok, Hungary. The crystals measured by Schmidt were mostly paper thin and striated so that the values recorded are not altogether reliable.

Crystals of claudetite from two sources have recently come into the hands of the author and proved to give such constant and consonant measurements that new elements have been based upon them. I am indebted to Mr. Wilke of Palo Alto for this material.

(*a*) Claudetite from Imperial Co., California:—The hand specimen is a whitish rock which appears to be an altered schist, largely sericitized. It contains lenses of massive realgar and thin veins, parallel to the schistose structure, of claudetite. Where they are open, the veins are lined with radiating masses of brilliant claudetite crystals, the largest a millimeter or more in diameter and up to 4 mm. long. With the claudetite are crystals of sulphur.

Two crystals were detached from the wall of a cavity without distorting them, the extraordinary softness and ease of cleavage of the mineral making this a matter of great difficulty.

Two excellent crystals were measured, and the angles obtained from these crystals are shown in the following table.

(*b*) Claudetite from Jerome, Arizona:—A small cavity 3 cm. across lined with beautiful silky crystals of claudetite comes from the United Verde Mine and is undoubtedly a product of the mine fire.[2] The crystals are plates or laths, terminated only at the free ends and measuring at maximum 3 by 10 mm. with thickness less than .5 mm. Both prism and terminal faces give excellent measurement. Four crystals were measured, one of which was a twin on (100). Table I presents the angles obtained from the claudetite crystals of both localities.

---

[1] *Zeit. Krist.*, vol. **14**, p. 575, 1888.

[2] See Lausen, C., Hydrous Sulphates formed under Fumarolic Conditions at the United Verde Mine: *Am. Mineral.*, vol. **13**, p. 203, 1928.

TABLE I

A—Crystals from Imperial Co., California

Form	No. of faces	ϕ	Range ϕ	ρ	Range ρ
110	5	67°38′	67°29′–67°53′	90°00′	
$\bar{1}01$	2	90 00	89 49 –90 01	37 51	37°47′–37°55′
$\bar{1}11$	1	−66 01	—	40 33	—
111	4	69 24	69 24 –69 25	44 49	44 44 –44 53

B—Crystals from Jerome, Arizona

Form	No. of faces	ϕ	Range ϕ	ρ	Range ρ
130	10	38 45½	37 12 –39 40	90 00	—
011	2	12 00	—	20 04	—
101	2	89 43	89 35 –89 50	43 00	—
$\bar{1}01$	4	−90 14	89 04 –90 30	37 53	37 38 –38 06
$\bar{1}11$	10	−65 52	64 43 –67 02	40 29	40 17 –40 45
111	6	69 23	69 09 –69 32	44 48	44 40 –45 03
$\bar{1}21$	2	−48 24	48 00 –48 49	46 15	46 13 –46 18

The projection elements were calculated separately for crystals of each locality with the following results:

	Imperial Co.	Jerome	Mean
p_0'	.8547	.8572	.85595
q_0'	.3487	.3499	.3493
e'	.0753	.0761	.0758
μ	85°41′	85°38′	85°40′

From these mean values the following elements are calculated, with which in adjoining column are the elements of Schmidt.

ELEMENTS OF CLAUDETITE

Palache		Schmidt	
$a=0.4092$	$p_0=0.8535$	$a=0.4040$	$p_0=0.8527$
$c=0.3493$	$q_0=0.3483$	$c=0.3445$	$q_0=0.3437$
$\beta=94°20'$	$\mu=85°40'$	$\beta=93°57'$	$\mu=86°03'$

Table II gives the calculated position and interfacial angles of all known forms of claudetite together with some of the observed angles of Palache and Schmidt. The table is based on Palache's elements.

TABLE II. CLAUDETITE ANGLE TABLE

			Average Calculated		Observed, Palache		Calculated			Observed, Schmidt		
			ϕ	ρ	ϕ	ρ	C	A	B	C	A	B
c	0	001	90°00′	4°20′	—	—	—	85°40′	90°00′	—	85°34′	90°00′
b	0∞	010	0 00	90 00	0°00′	90°00′	90°00′	90 00	—	—	90 00	—
a	$\infty 0$	100	90 00	"	90 14	"	85 40	—	90 00	85°34′	—	90 02
t	$^1/_{10}\infty$	1.10.0	13 46	"	—	—	88 57	76 14	13 46	—	—	14 33
v	$\frac{1}{5}\infty$	150	26 06½	"	—	—	88 06	63 53½	26 06½	—	—	—
s	$\frac{1}{3}\infty$	130	39 14½	"	38 45½	90 00	87 15½	50 45½	39 14½	—	—	39 03
μ	$\frac{2}{5}\infty$	250	44 25½	"	—	—	86 58	45 34½	44 25½	—	—	—
r	$\frac{1}{2}\infty$	120	50 47	"	—	—	86 38½	39 13	50 47	—	—	50 31
m	∞	110	67 48	"	67 38	90 00	85 59½	22 12	67 48	—	—	67 06
γ	01	011	12 15	19 40½	—	—	19 12½	85 54½	70 39½	—	85 48	71 02
β	02	021	6 11½	35 05½	—	—	34 51½	86 27	55 08½	—	—	55 03
α	04	041	3 06½	54 27	—	—	54 20	87 28½	35 40	—	—	—
d	10	101	90 00	42 58½	89 43	43 00	38 38½	47 01½	90 00	37 22	—	90 03
q	$\bar{1}0$	$\bar{1}01$	−90 00	37 57½	−90 14	37 52	42 17½	52 02½	"	42 24	—	90 22
o	1	111	69 27	44 51½	69 23½	44 48½	40 49	48 40	75 40	—	48 24	75 48
g	$\bar{1}$	$\bar{1}11$	−65 53	40 31½	−65 53	50 29½	44 30½	−53 37½	74 36	—	−52 13	74 43
h	$\bar{1}2$	$\bar{1}21$	−48 09½	46 19½	−48 24	46 15	49 37	−57 24	61 09	—	—	—
n	17	171	20 51½	69 05	—	—	67 36	70 34½	29 12½	—	—	—

It will be noted in this table that the agreement of calculated position and interfacial angles with observed angles is for almost all forms excellent. Reference to Schmidt's article will show further that for interfacial angles his measurements agree better in all cases with the calculated values from the new elements than with his own calculated values. There seems no doubt that the new elements are established.

The habits of the claudetite crystals from the two new localities are shown in figures 1 and 2.

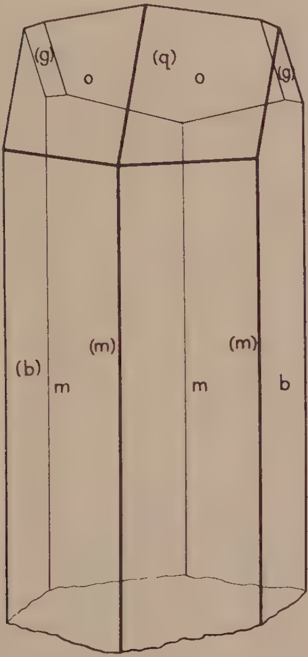

Fig. 1

Claudetite, Imperial Valley, Calif.

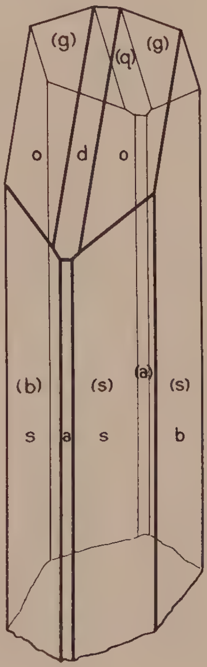

Fig. 2

Claudetite, Jerome, Ariz.

MINASRAGRITE

Minasragrite is a highly hydrous sulphate of vanadium first described and named by Schaller.[3] As the name implies, the mineral was found at the vanadium mine at Minasragra, Peru, where it occurs as a blue incrustation on patronite. Schaller described the physical properties of the new mineral and assigned to it the formula $V_2O_4.3SO_3.16H_2O$. He found no measureable crystals but determined from its optical properties that it was monoclinic or triclinic.

---

[3] Schaller, W. T., Minasragrite, a hydrous sulphate of vanadium: *Wash. Acad. Sci. Jour.*, vol. **7**, p. 501, 1917.

Specimens of patronite in the Harvard mineral collection, which in the course of many years have become coated with various alteration products, showed in places a vivid blue incrustation which proved to be minasragrite. The crust is composed of minute but very perfect crystals forming an open net work which falls to pieces at a touch. Some of the tiny crystals are quite complete and proved to be measureable. The two best which were completely measured, have an average diameter of .2 mm. and a maximum dimension of .25 mm. Notwithstanding their minute size the crystals gave excellent reflections and proved to be monoclinic. The habit of the crystals is shown in figure 3. The measured and calculated angles of the forms are contained in Table I. Table II contains calculated interfacial angles.

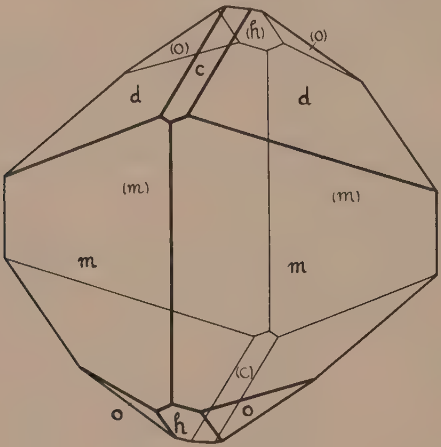

Fig. 3. Minasragrite

No close relation in form to any previously described sulphate is apparent from these angles.

Efforts to prove the presence of any distinct cleavage were not successful. The crystals were so minute that the handling of them

TABLE I. ANGLE TABLE FOR MINASRAGRITE

$a=0.7196$	$p_0'=0.9905$	$p_0=0.9251$
$c=0.6656$	$q_0'=0.6656$	$q_0=0.6216$
$\beta=110°57'$	$e'=0.3827$	$\mu=69°03'$

			Calculated		Measured				
			ϕ	ρ	ϕ	Range	ρ	Range	No. of faces
c	0	001	90°00′	20°57′	90°22′	90°00′–90°44′	21°01′	20°56′–21°06′	2
m	∞	110	56 06	90 00	56 09	56 04 –56 15	90 00	—	7
d	01	011	29 54	37 31	29 50½	29 16½–30 07	37 31	37 21 –37 35	4
h	$\bar{1}0$	$\bar{1}01$	−90 00	31 17½	90 00	−90 05 –89 55	31 17	31 10 –31 24	2
o	$\bar{1}$	$\bar{1}11$	−42 24	42 02	42 16	42 05 –42 31	42 02	42 00 –42 02	3

TABLE II. INTERFACIAL ANGLES OF MINASRAGRITE

Angle to 001		Angle to 100		Angle to 010	
m	72°44′	*m*	33°54′	*m*	56°06′
d	31 52	*d*	72 19½	*d*	58 08
h	52 14½	*h*	58 42½ (to $\bar{1}00$)	*h*	90 00
o	57 50½	*o*	63 10 (to $\bar{1}00$)	*o*	60 22

was difficult. There seems to be a tendency to break in the general direction of the side sinacoid but with no true cleavage parallel to that plane as Larsen suspected on optical ground.

SAMSONITE

The crystal form of samsonite has been described by three authors whose measurements yield closely agreeing results. W. Bruhns[4] calculated elements from three angles between two forms. His position differs from that adopted by later observers and here used. Calculating his measurements to the new position, we obtain the elements:—

$$a=1.2787, \qquad c=0.8204, \qquad \beta=92°42'$$

F. Slavik[5] gave a fuller description based on the measurement of many crystals. His elements, derived from three angles between three forms, are:—

$$a=1.2776, \qquad c=0.8180, \qquad \beta=92°46'$$

The third description is by F. Kolbeck and V. Goldschmidt,[6] who measured six crystals on the two-circle goniometer. The elements calculated from their two best crystals are:—

$$a=1.2777, \qquad c=0.8192, \qquad \beta=92°42'$$

The author measured five crystals, also by the two-circle method and his calculation yielded the elements:—

$$a=1.2786, \qquad c=0.8217, \qquad \beta=92°34'$$

Since these four independent values for the elements are in such close agreement, it was felt that the mean of all of them was better than any one. This mean value is as follows:—

$$a=1.2782, \qquad c=0.8198, \qquad \beta=92°41'$$
$$p_0=0.6414, \qquad q_0=0.8189, \qquad \mu=87°19'$$

An angle table was calculated from these elements and has been published elsewhere.[7] Table I contains the position-angles for all

---

[4] Kristallform des Samsonit von St. Andreasberg, *IV Jahresb. d. Niedersächs. geol. Vereines, Hannover*, **1911.**

[5] Morphologie des Samsonits, *Bull. internat. de l'acad. des sciences de Bohême*, **1911,** p. 16.

[6] Ueber Samsonit von Andreasberg, *Zeit. für Krist.*, vol. **50,** p. 455, 1912.

[7] Crystallographic Angle-Tables, 1933. Dept. of Mineralogy, Harvard University, privately printed.

TABLE I

Samsonite, calculated and measured angles

		Calculated		Measured		Limits		No. of faces	xls.	Quality
		φ	ρ	φ	ρ	φ	ρ			
b	010	0°00′	90°00′	—	—	— —	— —	—	—	
a	100	90 00	"	90°17′	90°00′	90°04′–89°43′	— —	2	2	v. poor
q	140	11 04½	"	12 46	"	— —	— —	1	1	poor
s	130	14 38	"	14 25	"	14 11 –14 34	— —	6	3	v. good
n	120	21 23	"	21 39	"	— —	— —	1	1	v. poor
m	110	38 04	"	37 37	"	37 33 –38 08	— —	9	5	good
l	210	57 27	"	58 01	"	56 55 –58 38	— —	3	3	poor
k	012	6 31½	22 25	4 33	22 37	— —	— —	1	1	good
i	011	3 16½	39 23½	—	—	— —	— —	—	—	
f	103	90 00	14 37½	90 04	14 32	90 01 –90 11	14°18′–14°42′	5	5	good
d	101	"	34 34	90 04½	34 32	" "	34 28 –34 38	4	4	v. good
e	$\bar{1}01$	–90 00	30 46	–90 02	30 53	90 00 –90 04	30 49 –30 57	4	4	good
g	$\bar{3}01$	"	61 59	–90 01	62 12	— —	— —	1	1	good
h	$\bar{5}01$	"	72 27½	–90 02	72 29½	90 02 –90 04	72 25 –72 34	2	2	good
p	111	40 02½	46 57½	—	—	— —	— —	—	—	
π	$\bar{1}11$	–35 59	45 22½	–36 06	45 30½	35 47 –36 17	45 25 –45 47	9	5	v. good
r	212	59 15	38 43	—	—	— —	— —	—	—	
x	$\bar{1}21$	–19 57	60 10½	–20 15½	61 01½	20 08 –20 23	60 38 –61 25	2	2	poor
δ	$\bar{4}73$	–22 56	64 17½	–22 59	64 28	22 53 –23 04	64 24 –64 35	3	2	poor

the forms hitherto observed and, for the forms observed by the author, the measured angles.

In Table II there are shown the forms found by the various observers.

TABLE II

Forms of Samsonite by various observers

		Bruhn's symbol	Slavik	Kol. & Gold.	Palache
b	010	010	—	x	—
a	100	—	x	x	x
q	140	—	x	—	?
s	130	—	?	?	x
n	120	140?	x	—	—
m	110	120?	x	x	x
l	210	—	x	x	?
k	012	—	—	—	x
i	011	—	—	x	—
f	103	$\bar{2}03$	x	—	x
d	101	$\bar{1}01$	x	—	x
e	$\bar{1}01$	001	x	—	x
g	$\bar{3}01$	101	x	—	x
h	$\bar{5}01$	201	—	—	x
p	111	$\bar{1}11$	—	x	—
π	$\bar{1}11$	011	x	x	x
r	212	$\bar{2}12$	—	—	—
x	$\bar{1}21$	—	—	—	x
δ	$\bar{4}73$	—	x	—	x

It is somewhat remarkable that the forms observed by the four observers are so different, for the mineral samsonite seems to have been found in only two vugs in the Samson shaft at the St. Andreasberg mine and one would expect more uniformity in the habit of the crystals. The total absence of the orthodome forms on the crystals of Kolbeck and Goldschmidt is in strong contrast to their strong development in all others measured. The author's study establishes (130) as a well-developed member of the form series and adds the two forms *k*(012) and *x*($\bar{1}21$), both weakly developed.

NATIVE SELENIUM

The element selenium has never been certainly identified as a mineral; nor have crystals of the metallic gamma-selenium ever been made artificially which were accurately measureable. Muthmann[8] has, it is true, figured a combination of prism and rhombohedron of this substance, but the figure is based on approximate measurements on the microscope stage of the edges of minute crystals, and these measurements by no means justify his assertion that selenium is completely isomorphous with tellurium.

Much interest, therefore, attaches to specimens of selenium found in the fire-zone of the United Verde Mine which, like the claudetite already described, were secured through Mr. Wilke.

There are several hand specimens of quartzite and of fire-fritted sandstone partly encrusted with needles of selenium. The needles may reach a length of 2 cm. with a diameter not over 1 mm. Sometimes they are clustered in flattened sheets parallel to a prism face so that patches up to 5 mm. across reflect together. On one specimen the selenium is in melted films or in droplets of dark red glass. Loose crystals up to 2 mm. long were also present and while clearly of hexagonal form were generally bent and twisted so that they could not be measured. Many of the crystals were hollow and tube-like with facets on the edges. A few tiny crystals about .5 mm. in length proved to be undistorted and gave excellent reflections on the goniometer. They always showed the prism of the first order, *m*, and a rhombohedron. On the best crystal faces of other forms were found. The table shows the observations made on this crystal.

		No. of	Measured				Calculated	
		faces	φ	Range	ρ	Range	φ	ρ
m	$10\bar{1}0$	5	30°02′	±11′	90°00′	0	30°00′	90°00′
a	$11\bar{2}0$	2	00 04	± 1	"	0	0 00	"
h	$21\bar{3}0$	4	19 22	±15	"	0	19 06	"
r	$10\bar{1}1$	3	−30 07	±11	52 40	±4′	−30 00	52 38
e	$01\bar{1}2$	1	29 17	—	34 20	—	30 00	33 13
f	$11\bar{2}3$	1	0 06	—	37 33	—	0 00	37 05½

---

[8] *Zeit. f. Krist.*, vol. **17**, p. 357, 1889.

The mean angle ρ of the unit rhombohedron from the seven best readings on four crystals is 52°38′ with a range of 52°36′–52°43′. Calculating from this angle, we obtain the axial ratio and angles shown below in comparison with those of tellurium.

	c	p_0	$c\wedge r$	$r\wedge r$
Se	1.134	0.7550	52°38′	86°59½′
Te	1.330	0.8867	56 55½	93 03

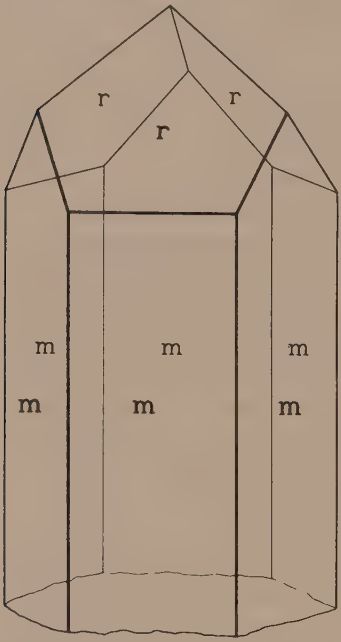

Fig. 4. Crystal of Native Selenium showing the forms $m(10\bar{1}0)$ and $r(10\bar{1}1)$.

Two crystals showed minute faces in the position of the negative rhombohedron. It was impossible to determine whether these were due to twinning on the vertical axis with complete penetration or to the normal development of this form. Figure 4 shows, idealized, the habit of the average crystal.

Cleavage of good quality was occasionally visible but, because of the softness and extreme flexibility of the crystals, it was very difficult to develop it without rendering the crystal unmeasureable. Approximate measurement showed, however, that it was parallel to the negative rhombohedron $e(01\bar{1}2)$. In tellurium the cleavage is prismatic and basal, another point of difference between the two elements.

A sample of the very homogeneous crystals was analyzed by F. A. Gonyer and proved to be without a trace of tellurium and to have but a trace of sulphur.

INDIUM

A sample of crystallized indium, prepared in the Harvard Chemical Laboratory by Chester M. Alter in 1932, was studied by Dr. M. A. Peacock. The sample consisted of arborescent groups of brilliantly silver-white crystals. Some of the groups were several centimeters long, but the individuals composing them were less than a millimeter in any dimension. The substance is so soft and wax-like that only occasionally could a crystal be detached without distortion. The symmetry proved to be tetragonal with close approach to isometric form. The angle $c \wedge p$, $(001) \wedge (111)$, is 56° 35′, the mean of nine measurements with the range 56°10′–57°00′. The value of c calculated from this angle is 1.072. The forms observed are $c(001)$, $a(100)$, $m(110)$ and $p(111)$. The arborescent groups were largely developed by elongation of the crystals parallel to an a-axis.

A MODEL FOR BIAXIAL CRYSTALS

AUSTIN F. ROGERS, *Stanford University.*

Most students have difficulty in visualizing the optical relations in biaxial crystals and the instructor finds it helpful to use models of some kind to supplement the diagrams given in the textbooks. Various models of the wave-surfaces, Fresnel ellipsoids, and index ellipsoids have been made and may be procured from German dealers. In my course in crystal optics I employ the index ellipsoid exclusively, following the suggestion of F. E. Wright.[1] A model of a triaxial ellipsoid is almost indispensable but it is hardly adequate to elucidate all of the important optical features of biaxial crystals.

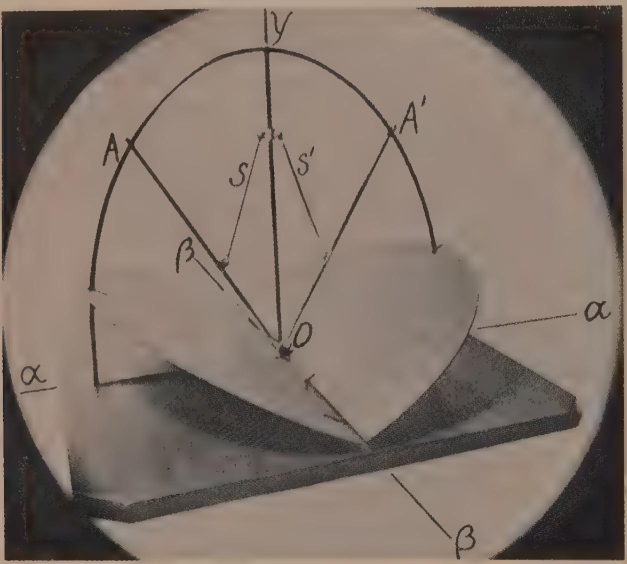

FIG. 1. Model to illustrate the optical properties of biaxial crystals. It is essentially half the index ellipsoid of a positive crystal in which the axial angle *AOA'* may be varied from 7 or 8° up to nearly 90°. (About one-sixth natural size.)

I have found the model illustrated in the accompanying photograph very useful in class work. It is a model of one-half of the index ellipsoid. While none of the actual surface of the ellipsoid is present, all of the important optical directions are represented.

---

[1] *Am. Jour. Sci.* [4], vol. **35**, pp. 133–138, 1913.

The model is constructed upon a polished wooden base about 36 cm. square and 13 mm. thick. The half-ellipse in a vertical position represents the optic axial plane. The vertical standard, a brass rod of 4 mm. diameter, is γ and the major semi-axis of the ellipse corresponding to n_γ is 24 cm. long. The direction approximately horizontal in the photograph and at a right angle to γ in the model is α. The length of the minor semi-axis of the ellipse corresponding to n_α is 15 cm. The optic normal at right angles (in the model) to both γ and α is β and the intermediate semi-axis n_β is $17\frac{1}{2}$ cm. long.[2] The semi-circular discs with radii equal to n_β ($17\frac{1}{2}$ cm.) are halves of the circular sections of the ellipsoid. These discs are made from black sheet bakelite 2 mm. thick. They fit into metal hinges which move about β; the other parts of the hinges are attached to the wooden base. The rods *AO* and *A′O* represent the optic axes. The outer portions of the optic axes are hollow rods into which the inner solid rods fit, and along which they slide. The inner solid rods are permanently attached to the centers of the semi-circular discs and in a position normal to the discs.

The optic axes and the semi-circular discs move simultaneously and this is brought about by the aluminum rods *s* and *s′*, the lower ends of which are permanently fixed to the hollow portions of the optic axes. The upper ends of the rods *s* and *s′* are attached to a kind of hollow toggle-joint which slides up and down on γ. It is to be regretted that the rods *s* and *s′*, which do not in any way represent optical directions, have to be present, but it is essential that the axial angle shall always be bisected by γ. The model was at first constructed without these rods and the aspect of the model often with a small V on one side of γ and a large V on the other side was most disconcerting.

The angle 2V between the optic axes may be varied from 7 or 8° up to nearly 90°. The semi-ellipse is notched at intervals of 10° so that the approximate value of 2V may be read off. The semi-circular discs have slits $2\frac{1}{2}$ cm. long in the direction of the optic axial plane; this is necessary in order that 2V may be made as small as possible. The radius of the circular sections should of course vary with the size of the axial angle but this seems hardly practicable in a model of this kind. In the present model the circular sections have the correct radius for a value of 2V of about 75°.

---

[2] I use α, β, and γ for directions and n_α, n_β, and n_γ as indices of refraction for the corresponding directions.

The model illustrated is for optically positive crystals, since the value of n_β is closer to n_α than to n_γ. A model for optically negative crystals could be constructed by making n_β closer to n_γ than to n_α. In this case it would be necessary to have α in a vertical position since in negative crystals it is the acute bisectrix.

A possible improvement in the model could be made by adding a semi-ellipse $\gamma\beta$ and an ellipse $\beta\alpha$ made of brass rods bent to shape. The model then would doubtless look more like the index ellipsoid, but the optic axial plane would be less prominent. The semi-circular discs can be easily removed. Therefore it would be feasible to have a number of interchangeable discs with radii of different lengths, but this would seem to be an unnecessary refinement.

The model described in this article was constructed by Mr. Frank D. Banham, chief mechanician at Stanford University.

THE SOURCE OF VANADIUM, MOLYBDENUM, TUNGSTEN, AND CHROMIUM IN OXIDIZED LEAD DEPOSITS

W. H. Newhouse, *Massachusetts Institute of Technology.*

Introduction

The source of the vanadium and molybdenum in oxidized lead deposits has always been an enigma.

Vanadium is present in small amounts in rocks and residual soils. This is usually considered as the source of the vanadium in the oxidized ores. The presence of molybdenum has been accounted for in several ways. The source usually suggested is microscopic crystals of molybdenite present in the hypogene ore. Other suggestions made are that it is derived from adjoining rocks, or that the wulfenite was formed by hypogene solutions.

The present paper will call attention to the presence of small amounts of these elements in common sulphides. It is the writer's belief that this is the common source for these elements in the oxidized lead deposits, although important contributions may have been made from the wall rocks in some places. Usually these metals, where found, form only small percentages of the oxidized ore.

Distribution and Tenor of Vanadium in Oxidized Lead Ores

Vanadium is widely distributed in small percentages in the oxidized lead and lead-copper ores, in southwest United States, Mexico and part of South America, in certain localities of Spain, and parts of southern Africa.

In western United States,[1] particularly in Arizona, New Mexico, and to a less extent in Nevada and California, lead vanadate is found although seldom in high grade pockets. These deposits almost invariably carry only 0.1 to 0.6 per cent V_2O_5. The deposits[2] are of lead sulphide with some accompanying zinc and copper sulphides which carry vanadium compounds in the oxidized zone. The vanadium compounds include vanadinite, and isomorphous mixtures containing vanadium, arsenic, and phosphorus with lead, zinc, and copper, in varying proportions.

---

[1] Conley, J. E., *U. S. Bur. Mines*, Bull. **212**, pp. 239–240, 1923.

[2] Hess, F. L., *U. S. Geol. Survey, Mineral Resources*, vol. **1**, p. 956, 1917.

The deposits are small; none known in 1917 was large enough to furnish ore for a plant of considerable size. In several deposits near Cutter, New Mexico, about 1.0 per cent vanadium oxide is present as vanadinite.[3] Descloizite, wulfenite, galena and other minerals are associated with the vanadinite.

At Kelvin, Arizona, vanadinite ore with associated wulfenite carried 3–5% vanadic oxide[4] while the C and B vanadium mine near Christmas, Arizona, contained 500 tons of ore carrying 1–3% V_2O_5. At the Shattuck Mine, Bisbee, Arizona, 3000 tons of oxidized ore carried 10% vanadic oxide, and a large tonnage carried 1–1.5%. Vanadinite and sometimes cuprodescloizite and wulfenite are found at many places in the Cordilleran of Mexico,[5] in the region extending from Hidalgo to Chihuahua. Some bodies of ore found in Zacatecas carry over 4% vanadic oxide.

Vanadium is widely distributed in small percentages in the oxidized lead ores of Argentina and Bolivia, South America. Almost every oxidized ore tested in this large region was found to contain some, although the amount is usually small.[6] Deposits[7] worked in the Province of Cordoba, Argentina, gave a product of 10% vanadium oxide and copper veins at Talcuna, Chile, contained 6%. Much of the early vanadium ore came from Spanish deposits, apparently from Santa Marta in southwestern Spain.[8] These ores as mined contained four to five per cent vanadic oxide. Lead vanadate and other minerals form the ore. Clays present are also rich in vanadium. Vanadium ores of this type have been found in Northern Rhodesia and also in Southwest Africa; and the Transvaal.

At Broken Hill, Rhodesia[9] a large tonnage, 935,000 tons, of oxidized ore carries 0.9% V_2O_5 while a very much smaller tonnage carries 3.5%.

---

[3] Curran, T. F. V., Vanadium ores and uses: *Eng. & Min. Jour.*, vol. **93**, pp 1093–4, 1912.

[4] Vanadium ores monograph, *Imperial Institute*, London, pp. 51–52, 1924.

[5] Curran, T. F. V., *Eng. & Min. Jour.*, vol. **93**, p. 1093, 1912.

[6] Whitehead, W. Oral communication.

See also Bodenbender W., Bleiglanz—Vanadin und Molybdanerzgang in der Provinz S. Luis Argentinen, Süd Amerika: *Zeit. für Prakt. Geol.*, vol. **9**, pp. 51–55, 1901.

[7] De Launay, L., *Traité de Metallogenie.* Gites Mineraux et Metalliferes, vol. **1**, pp. 725–726, 1913.

[8] Smith, J. Kent, The present source and uses of vanadium: *Trans. Am. Inst. Min. Eng.*, vol. **38**, pp. 699–700, 1908. Vanadium ores monograph. *Imperial Institute,* p. 31, 1924.

In southwest Africa,[10] a number of deposits have been worked, the origin of which is doubtful. Those in the northwest part carry vanadates of lead-copper, with little or no zinc, while those in the southeast carry lead-zinc vanadates with little copper. The deposit at Abanabe is the most important. Small deposits in the Marico district, Transvaal, carry 2.8% vanadic oxide, and one near Messina carries 22% vanadic oxide.[11]

In summarizing, it may be said that there is a fairly wide distribution of vanadium in oxidized lead ores to the amount of 0.1 to 1.0% V and less. It appears to be most commonly found in areas of deep extensive weathering, but it should be observed that so far as the data go, they do not appear to be coextensive with deeply oxidized regions. Rather they are apparently found only within certain areas or parts of deeply oxidized regions. Locally much higher concentrations of vanadium are found. These deposits are commonly present in relatively small tonnages compared with those just mentioned. They usually contain less than 6.0% V.

TESTS FOR VANADIUM

The presence of vanadium in sulphides was determined chemically as well as spectroscopically. Two chemical tests were used; one, the well known hydrogen peroxide test, and the other, the strychnine sulphate test with concentrated sulphuric acid. Complete details of procedure are given in the works cited,[12] and will

---

[9] Walker, G. L., *Eng. and Min. Jour.*, vol. **125,** p. 733, 1928.

[10] Wagner, P. A., *Memoir* **7**, *Union of S. Africa, Geological Survey*, pp. 89–90, 1916.

Imp. Inst. Vanadium Monograph, pp. 20–21, 1924.

Stahl, A., Erzlagerstätten des Otavi-Berglandes: *Zeit. für Prakt. Geol.*, pp. 150–151, 1926.

Guide Book **15** *Session Inter. Geol. Cong.*, Excursion C 21, pp. 44–45, 1929.

Clark, Alex. W., The ore deposits of the Otavi Mountains, Southwest Africa: *Min. Mag.*, Vol. **44,** 265–272, 1931.

[11] Vanadium Monograph, *Imperial Institute*, London, pp. 22–23, 1924.

[12] Conley, J. E., Vanadium: *U. S. Bur. Mines*, Bull. **212,** pp. 241–262, 1923.

Gregory, A. W., A colorimetric method for the estimation of small quantities of vanadium: *Chem. News*, vol. **100,** p. 221, 1910.

Fenner, J. A., Determination of tungsten and vanadium in the presence of titanium: *Jour. Soc. Chem. Ind.*, vol. **37,** p. 609A, 1918.

Treadwell and Hall, *Analytical Qualitative Chemistry*, vol. **1,** p. 541, 1930.

not be redescribed here, but certain features may be mentioned. Weighed amounts of sulphides, one to several grams in the several types of procedure used, were dissolved in acid or fused in a nickel crucible and the contents extracted with water.

The hydrogen peroxide test was made on these solutions and also after precipitating the iron in the acid solutions with sodium carbonate and hydrogen peroxide, or with ammonia. The filtrates were tested, after acidifying or after acidifying and concentration by evaporation. Chromium is not present in sufficient amounts to show in the ether ring test, which was made on material from all the localities. Phosphoric acid was added to destroy any color due to iron, NH_4F was added to prevent any color due to titanium. It was known that large quantities of molybdenum and cerium were not present. The residual light yellow, orange to brownish color obtained was compared in tubes with that produced by known concentrations of vanadium, and the results checked against those obtained by the use of strychnine sulphate. The strychnine sulphate test is made in a solution from which the iron has been removed by precipitating with sodium carbonate and hydrogen peroxide. The presence of much water interferes with the test from the quantitative standpoint, and this was overcome by acidifying with large amounts of concentrated sulphuric acid, before adding the strychnine sulphate. This makes the test less desirable than the one using hydrogen peroxide, although the final orange coloration of the solution containing vanadium is very distinctive. Both these tests are very delicate. The coloration due to .001% or less of vanadium may easily be seen when viewed down long tubes against a white background. Numerous blank tests were made on the reagents employed.

The spectroscopic analysis was made by G. E. Claussen in the spectroscopy laboratory of the Massachusetts Institute of Technology under the direction of Professor G. R. Harrison. Two methods were used, first the spark method in which the mineral powders were packed into craters in highest purity graphite electrodes, about 6 mm. in diameter, and subjected to a condensed spark for ten minutes. In addition the arc method was employed on $HCl-HNO_3$ solutions of the minerals. Wedge shaped graphite electrodes were soaked in the solution and more of it was placed on the hot electrodes. The arc was exposed to the slit of the twenty-one foot concave grating for approximately one minute. The acids used in making the solutions were tested for purity and gave no lines other than those of the graphite electrodes.[13]

VANADIUM IN SULPHIDES

The tests for all elements were made on well crystallized material, mostly large individual crystals. The specimens were chiefly selected from localities which would furnish fresh, clean crystals, in order to avoid the possibility of contamination or "salting" by alteration processes.

The results as given are not considered of good quantitative value, but it is believed that they indicate approximate amounts. The amount of vanadium in the sulphides examined was found to be quite variable.

Five different samples of each of the minerals pyrite, sphalerite and galena from different localities were spectroscopically analyzed. Vanadium was found in the pyrite from Elba, and in galena from Leadville, Colo.; the Utah Apex Mine, Bingham Canyon, Utah; Przibram, Bohemia; Bleiberg, Karnten; and Joplin, Mo. The number of lines present in the spectra suggest that vanadium is present to the amount of .0n–.00n%.

These results are in harmony with those obtained chemically by the writer. The pyrite from Elba was found by the chemical tests to contain about 0.01% V while pyrite from Red Cliff, Colo.; Bingham Canyon, Utah; Leadville, Colo. and Central City, Colo. showed much less. Two of these latter which were examined spectroscopically with negative results, apparently contain the vanadium in amounts below ready spectroscopic detection.[14]

Negative spectroscopic results were obtained on the sphalerite from five different localities, although both chemical tests indicate its presence in four of these in amounts smaller than in the pyrite. This small amount is present in sphalerite from Kisbanya, Ungarn, Oradna, Siebenburgen; Lautenthal, Harz; and Warren, N. H. Less to none was chemically found in the sphalerite from Joplin, Mo.; Santander, Spain; Sonora, Mexico; and Rabenstein in southern Tyrol. The chemical tests on galena check the spectroscopic results. Vanadium ±.1% has been reported [5] in nickeliferous pyrite from the Merensky horizon in the Bushveldt Complex, S. Africa.

---

[13] Details are given in a paper by Claussen, see *Am. Mineral.*, vol. **19**, pp. 221–225, 1934.

[14] A considerable number of distinctive spectral lines are produced by a chloride solution of vanadium which contains 0.01% V and none from solutions containing 0.001% V.

Twyman, F. and Smith, D. M., *Wavelength Tables for Spectrum Analysis.* Adam Hilger, pp. 78, 100–101, 1931.

It is realized that other factors besides percentage of element may determine the presence or absence of spectral line.

SOURCES OF VANADIUM IN THE OXIDIZED LEAD-ZINC-COPPER DEPOSITS

It is evident that several sources contribute vanadium to the oxidized heavy metal deposits. Rocks, circulating waters, and hypogene mineralization probably all furnish their quota each of which may well vary greatly in different localities. The average vanadium content in igneous rocks is .017%V.[16] More is present in the femic than in the silicic or feldspathic rocks. It has been known for some time[17] that clays, residual, limonitic and lateritic soils were more than ordinarily rich in vanadium. This has been confirmed by many new analyses given by Jost[18] who finds less than .001%V in limestomes and dolomites, about .01% in clays and shales, from .03–.05% in bauxites and laterites, and .04–.1% in residual iron and manganese ores. The bulk of the oxidized lead deposits containing vanadinite are found in limestones, dolomites and granitic rocks. These are the lowest in vanadium of all rocks.

Jost advances the hypothesis that the vanadium in the vanadinite deposits is derived from lateritic and other residual soils.[19]

It may well be pointed out that the vanadium has been concentrated in these soils for the same reason that the iron and aluminum have been concentrated, namely due to the insoluble nonfugitive character of the compounds formed. They go into solution and are removed by meteoric waters with difficulty; otherwise, they would not be "residual." Certain deposits, which like the Spanish ones are found in rocks high in vanadium, doubtless re-

---

[15] Wagner, P. A., and Schneiderhöhn, H., *Platinum Deposits and Mines of South Africa*, pp. 234–236, 1929.

[16] Clarke, F. W., and Washington, H. S., The Composition of the Earth's Crust: *U. S. Geol. Survey*, Prof. Paper **127**, 20, 40, 1924.

[17] Clarke, F. W., Data of Geochemistry: *U. S. Geol. Survey*, Bull. **770**, pp. 722–723, 1924.

Lindgren, W., Mineral Deposits, pp. 395, 460, 1928.

[18] Jost, Konrad, Über den Vanadiumgehalt der Sedimentgestein Chemie der Erde, vol. **7**, Pt. 2, pp. 280–283, 1932.

[19] Jost, K., *Op. Cit.*, p. 282.

ceive much from that source. The occurrence of vanadium minerals in the Colorado carnotite deposits, and at Mauch Chunk, Pennsylvania, shows that vanadium may migrate at least to some extent in solutions, presumably of meteoric origin. Such circulating waters may at times contribute vanadium to oxidizing lead deposits.

The sulphides, pyrite, sphalerite, and galena, are, however, doubtless the chief contributing source for the more common widely distributed low grade deposits. Rich high grade deposits connected with large bodies of oxidized ore, derived from large original masses of sulphides like those at Broken Hill in N. Rhodesia, may also be in part of this origin.

Obviously, the vanadium must not only be present but also it must be available, i.e. amenable to solution. Femic igneous rocks may be rich in vanadium (0.027%V) where it is probably mainly present in titaniferous magnetite[20] and to a smaller extent in silicates. Magnetite is a relatively insoluble mineral in meteroic waters. As might be expected abundant vanadinite deposits are not found in these rocks. Much the same reasoning will apply to lateritic residual soils as a source. On the other hand, limestones and dolomites, although they contain less vanadium than other sediments, are readily dissolved by the acid solutions from oxidizing pyritic ores, and would hence probably contribute some in most deposits. Sulphide oxidation would precede any extensive lateritization, so these mineral acid solutions would probably not permeate the lateritic soils to any extent.

THE OCCURRENCE AND TENOR OF MOLYBDENUM IN OXIDIZED LEAD ORES

The oxidized ores of lead carry molybdenum chiefly as the mineral wulfenite[21] ($PbMoO_4$) which may contain some tungsten, chromium, vanadium, copper and calcium.

Wulfenite is widely distributed in varying but generally small amounts in lead ores that have been subjected to prolonged oxidation. In most places where found it has furnished specimens only of mineralogical interest. Hess has mentioned the fact that wulfenite is generally not present in any considerable amounts in the oxidized zones of large lead deposits in most of our mining centers. Deposits of commercial interest have been worked in Spain, in southwestern United States, Mexico, Austria, Germany and Yugo-Slavia.

---

[20] Pope, F. J., Investigation of magnetic iron-ores from Eastern Ontario: *Trans. Am. Inst. Min. Eng.*, vol. **29**, pp. 395–397, 1899.

[21] Dana, *System of Mineralogy*, pp. 989–991, 1914.
Hintze, *Handbuch der Mineralogie*, Bd. 1. Abt. 3, Hft. 2, pp. 4044–4059, 1930.
Rastall, R. H., Molybdenum ores. Monograph, *Imper. Inst.*, **1922.**
Hess, F. L., Molybdenum deposits: *Bull. U.S.G.S.* **761**, pp. 6–31, 1924.

Among the localities which contained wulfenite and were worked to some extent in past years are, Bleiberg, Carinthia; Rezbánya, Hungary; Przibram, Bohemia; Eureka, Nevada; and the Wheatley Mine, Pennsylvania. Considerable variation in the tenor of the molybdenum is found. The following brief review is intended to give some idea of its quantity. At the Mammoth and Collins Mines, Schultz, Arizona, the oxidized ore bodies contain about 1–2% wulfenite.[22] One shoot averaging 10–12 inches wide contained 20–30% wulfenite. The average run of ore from the Old Yuma mine, Pinal County, Arizona, contains not over 2–3 per cent wulfenite.[23] A vein 25 miles west of Tucson is said to show 2–3 per cent,[24] and one about 29 miles from the same city is said to carry 3 per cent wulfenite. A deposit near Twin Bridges, Montana,[25] carries 1/2–1 per cent wulfenite. Pure wulfenite contains 26.15 per cent molybdenum, so these deposits generally run about 0.15–0.80% Mo. In the provinces of Granada and Almeria, Spain, oxidized lead ores in limestone average about 1% Mo[26]. An average of 0.08% Mo is present in some Carinthian wulfenite ores.[27] According to Hess the wulfenite ores of the United States, Mexico, Austria and Spain carry greatly varying percentages of molybdenum but the average is probably less than 1%.[28]

Test for Molybdenum in Sulphides

The presence of molybdenum in sulphides was determined spectroscopically and by means of two chemical tests. The chemical tests are, first, the well known ammonium or potassium thiocyanate test in which, after the addition of this reagent, metallic zinc or stannous chloride is added, the red color due to the presence of iron will disappear and the reddish color indicative of the presence of molybdenum will appear. The writer prefers to use stannous chloride as a reducing agent where small amounts of both iron and molybdenum are present. The color due to the molybdenum may be collected and concentrated in a little ether, which after shaking forms a ring containing the color on top of the solution. This test is delicate and is said to be infallible.[29]

---

[22] Horton, F. W., Molybdenum; its ores and their concentration: *U. S. Bur. Mines*, Bull. **11**, p. 47, 1916.

[23] Horton, *Op. Cit.*, p. 49.

[24] Horton, *Op. Cit.*, p. 50.

[25] Horton, *Op. Cit.*, p. 76.

[26] Rubio, D. J., and Gavala, J., Yacimentos de Molibdeno en las provincias de Granada and Almeria: *Boletin Instituto Geologico de Espana*, **39**, 2nd Ser. 19, pp. 167–193, 1918.

[27] Doelter, *Handbuch der Mineralchemie*, vol. **4**, Pt. 2, pp. 798–99, 1929.

[28] Hess, F. L., *Min. Res., U. S. Geol. Surv.*, Pt. 1, p. 907, **1917.**

The other test which was used is one given by Feigl. It is a spot plate[30] test in which a drop or two of neutral or slightly acid test solution is placed on a spot plate and then a fragment of potassium ethyl xanthate is added followed by two drops of 2N HCl. A red-blue color develops when a molybdate is present. This test is very delicate and according to Feigl, the leading authority in that field, is completely specific.

MOLYBDENUM IN SULPHIDES

Molybdenum was found present by the chemical tests described in pyrite and galena from a number of localities. The amount varies in material from different places.

An attempt was made to find the approximate percentage of molybdenum present by varying the concentration of the solutions obtained from the sulphides, and finding the limiting concentration between positive and negative tests for the element. Similar work was done on known solutions of molybdenum. Pyrite from five localities was spectroscopically examined and molybdenum was found present in four of them.[31]

The pyrite containing spectroscopic amounts of molybdenum came from near Philipsburg. Montana; French Creek, Pa.; the

---

[29] Bonardi, J. P., *U. S. Bur. Mines*, Bull. **212,** Molybdenum, p. 72, 1923.
Treadwell and Hall, *Analytical Chemistry*, *Qualitative Analysis*, vol. **1,** p. 543, 1930.
Roscoe, H. E., and Schorlemmer, C., *A Treatise on Chemistry*, vol. **2,** p. 1121, 1923.

[30] Feigl, Fritz, Qualitative analyse mit hilfe von Tupfel Reaktionen. *Leipzig*, p. 176, **1931.** The potassium thiocyanate test is also used by Feigl to obtain a spot plate reaction, pp. 175–176.

[31] A considerable number of diagnostic or distinctive spectral lines are produced by solutions containing 0.01% and few by solutions containing 0.001% Mo.

Commercial Mine, Bingham Canyon, Utah; and Central City, Colo. Pyrite from Elba gave much weaker chemical tests for molybdenum than the others just mentioned, and negative spectroscopic results were obtained on it since the percentage of molybdenum, was probably too low to give spectral lines. Galena from Przibram, Bohemia, contains spectroscopic molybdenum while none was found by this means in galena from Leadville, Colo.; Utah Apex Mine, Bingham Canyon, Utah; Bleiberg, Carinthia; and Joplin, Missouri. Chemical tests on these last four indicate the presence of the element to the amount of approximately 0.000n% Mo. Sphalerite from six localities gave negative spectroscopic results although several gave faint chemical reactions for the element.

Urbain[32] found molybdenum in five samples of sphalerite out of sixty-four samples examined.

There can be no doubt that the Mo is commonly present—as are also the V, W and Cr,—in solid solution in the sulphides, rather than as separate compounds such as molybdenite (MoS_2). A careful microscopic examination was made of the crystals analyzed but no molybdenite was found. It is known that molybdenite is present with these sulphides in some localities.

SOURCE OF MOLYBDENUM IN OXIDIZED LEAD ORE

Traces of molybdenum are present in igneous rocks, particularly the silicic ones,[33] and this source may contribute in some places. Certain organisms apparently take in molybdenum and accumulate it in their life processes.[34] Sedimentary rocks containing such organic remains would doubtless contribute some molybdenum, if they formed the wall rock of an oxidizing lead ore body. The presence of molybdenite accounts for the wulfenite in some oxidized lead deposits.[35]

Twyman, F., and Smith, D. M., *Wavelength Tables for Spectrum Analysis*, Adam Hilger, pp. 78, 93, 1931.

[32] Urbain, G., Analyse spectrographique des blendes: *Compt. Rend.*, Vol. **149,** pp. 602–603, 1909.

[33] Hillebrand, W. T., Distribution and quantitative occurrence of vanadium and molybdenum in rocks of the United States: *Am. Jour. Sci.*, vol. **6,** pp. 209–212, 1898.

Ferguson, J. B., Molybdenum in rocks: *Am. Jour. Sci.*, **37,** pp. 399–402, 1914.

[34] ter Meulen, H., Accumulation of molybdenum in some aquatic plants: *Chem. Abst.*, vol. **26,** p. 4628, 1932.

[35] Lindgren, W., *Mineral Deposits*, p. 985, **1928.**

The fact remains that in others the presence of molybdenite has not been demonstrated, although careful search for it has been made.[36]

It is the writer's opinion that a common partial source of the molybdenum is the small amount contained isomorphously in the primary sulphides such as pyrite, sphalerite and galena. The molybdenum present in these would be readily available to form wulfenite during the processes of oxidation. Galena has been suggested as a possible source before.[37]

Tungsten and Chromium

These two elements are present in small amounts in many oxidized lead deposits. Neither of these, so far as is known, commonly forms separate compounds, but are both contained in wulfenite,[38] while chromium is also found in vanadinite,[39] and other minearls.

The separate compounds such as crocoite ($PbCrO_4$) and stolzite ($PbWO_4$) are more rarely found in oxidized zones. Tungsten is present in most of the vanadium bearing oxidized lead deposits in the southwestern states.[40] It rarely exceeds 2%.

Hartley and Ramage found[41] chromium spectroscopically in a specimen of sphalerite, and the spectroscopic work on sulphides done at Massachusetts Institute of Technology shows its presence in galena from Leadville, Colo.; the Utah Apex Mine, Bingham Canyon, Utah; Przibram, Bohemia; Bleiberg, Carinthia and Joplin, Missouri. The amount is estimated as roughly 0.0n–0.00n%Cr.

The spectroscopic work further demonstrated the wide occurrence of tungsten in small amounts in sulphides. It was found in pyrite from near Philipsburg, Montana; Elba, French Creek, Pa.; Commercial Mine, Bingham Canyon, Utah; Central City, Colorado, and in sphalerite from Kisbanya, Hungary; Oradna, Siebenburgen; Lautenthal, Harz; and in the galena from Leadville, Colorado; Utah Apex Mine, Bingham Canyon, Utah; Przibram, Bohemia; Bleiberg, Carinthia and Joplin, Missouri. The amount is estimated as 0.0n–0.00n% W.

---

[36] Emmons, W. H., Enrichment of ore deposits: *U.S.G.S.*, Bull. **625**, p. 425, 1917. Butler, B. S., San Francisco Region, Utah: *U.S.G.S.*, Prof. Paper **80**, pp. 110, 195–96, 1913.

[37] Curtis, J. S., Silver lead deposits of Eureka, Nevada: *U.S. Geol. Surv.*, Mon. **7**, pp. 54–56, 64–71, 1884.

Butler, B. S., Geol. and Ore deposits of the San Francisco Region, Utah: *U.S.G.S.*, Prof. Paper **80**, pp. 110, 195–196, 1913.

Schmidt, C., Vorkommen von Gelbbleierz: *Zeit. für Prakt. Geol.*, p. 102, **1915.**

[38] Hess, F. L., Molybdenum deposits: *U.S.G.S.*, Bull. **761**, pp. 6–7, 1924.

[39] Hintze, C., *Handbuch der Mineralogie*, vol. **1**, No. 22, p. 618, 1924.

[40] Hess, F. L., Mineral Resources, *U.S.G.S.*, vol. **1**, p. 956, 1917; *U.S.G.S.*, Bull. **761**, p. 6, 1924.

[41] Hartley, W. N., and Ramage, H., *Jour. Chem. Soc.*, vol. **71**, p. 540, 1897.

CONCLUSION

In most of the lower grade and probably some of the higher grade deposits of vanadium and molybdenum in the oxidized zones of lead and lead-zinc-copper deposits, the vanadium and molybdenum are largely derived from small amounts present in the original sulphides.[42] Careful examination may later show that other hypogene minerals also contain these elements in small percentages.

The source of chromium and tungsten in the oxidized zones of lead deposits is also probably largely due to the small amounts of these elements present in the original sulphides.

The areal distribution of the oxidized lead deposits containing these elements is thought to be largely dependent upon the presence or absence of these metals and strong oxidation. The presence or absence of these metals in the primary sulphides, is presumably dependent on space lattice requirements to some extent, but the temperature of deposition and source of the solutions are probably more important factors. Careful study would probably show zonal relations of these metals within single districts.

The general lack of wulfenite and vanadinite in any considerable amounts in the oxidized zones of large lead deposits in many mining centers, is probably because these metals are not present in magmatic solutions from a source that yields large amounts of lead. If it were purely temperature control, occurrences would be expected somewhere in the vicinity of the large lead deposits, in some kind of zonal relation.

---

[42] After this paper was in press, H. Moritz (a) reported vanadium in sulphide ore from Tsumeb, South Africa. Tennantite, enargite, sphalerite, and other sulphides, as well as calcite and dolomite, contain around 0.001% vanadium. Pyrite may contain as much as 0.01% vanadium. Molybdenite is present in germanite and sphalerite to the amount of 0.01–0.001% molybdenum. Galena from this locality contains very small inclusions of patronite, the aggregate running 0.01–0.005% vanadium. The writer re-examined, with oil immersion objective, the material used in the present study, and was unable to find any patronite. It is believed that most or all of the vanadium, as well as the molybdenum, chromium, and tungsten, are present in solid solution in the material used in the present study.

[a] Moritz, H., Die Sulfidschen Erze der Tsumeb Mine, *Neues Jahrb. f. Min., B.B.* **67A**, pp. 130–134, 1933.

SPECTROSCOPIC ANALYSIS OF CERTAIN GALENAS, SPHALERITES, AND PYRITES

GERARD E. CLAUSSEN, *Polytechnic Institute, Brooklyn, N. Y.*

To supplement a study of some sulfide minerals by Dr. W. H. Newhouse of the Department of Geology of the Massachusetts Institute of Technology, the complete qualitative analysis of sixteen samples was undertaken by means of the emission spectra. The spectroscopic method of analysis was adopted to detect in the samples important traces (0.01% to 0.001%) of elements, particularly chromium, tungsten, vanadium, and molybdenum, that were suspected but whose determination by other means would have been laborious and uncertain. The results of the analysis demonstrate the value of a spectroscope having high dispersion in the analysis of minerals.

The samples, which are described in the accompanying table, were taken from large single crystals, except samples 5, 6, 7, 8, and 9; these were taken from coarsely crystalline, massive material. The samples were prepared in three forms: fragments about ¼ inch maximum dimension; powders of non-uniform grade, about 40 mesh; and solutions containing ten grams of the mineral in 50 cc. of a mixture of concentrated nitric and hydrochloric acids. The spectra of each sample produced by both the arc and the spark methods were recorded photographically with the aid of the 21 foot concave grating installed in a constant temperature and constand humidity room in the Spectroscopic Laboratory of the Massachusetts Institute of Technology.

ARC METHOD

Two wedge-shaped electrodes of highest purity graphite[1] free from titanium and vanadium were soaked with the acid-mineral solution. The solution, containing some of the precipitate that had formed, was dropped on the hot electrodes by means of a clean medicine dropper. The arc from each pair of electrodes was exposed to the slit of the 21 foot concave grating for approximately one minute, which was sufficient to develop all lines without overexposure. A preliminary examination of a pair of electrodes soaked in the acid reagent containing no mineral sample, performed on a Hilger E2 quartz spectrograph, revealed the presence of no lines other than those given by pure, untreated electrodes.

---

[1] Manufactured by the National Carbon Company Inc., Cleveland, Ohio.

SPARK METHOD

The powders were packed into craters in pure graphite electrodes, 6 mm. in diameter, and subjected to a condensed spark. The aggregate exposure for each powder was ten minutes; the craters were refilled at intervals of one minute. Attempts to spark the fragments themselves were unsuccessful; after the spark had passed for about ten seconds the fragments melted. It was found that the removal of a thin layer (0.2 mm. approximately) from the inside and outside of a crater effected the removal also of all traces of the mineral with which the crater had previously been packed.

ANALYSIS OF SPECTRA

Arc and spark spectra were obtained in the region: 2900 Å to 5800 Å, which occupied four Eastman "40" 4×10 plates. About 610 Å were included on each plate at a dispersion ranging from 2.60 Å per mm. in the ultra-violet to 2.50 in the green. Base lines, iron or air lines, or cyanogen band heads, were recognized with the aid of an Atlas.[2] Every unidentified line of the spark spectra was then measured with a paper centimeter scale reading to 0.1 mm. and identified in two standard wave-length tables.[3] The sensitive lines (de Gramont) of all the elements found in the spark spectra were sought in the arc spectra. Confusion of the line sought with neighboring iron, cyanogen, or air lines was avoided by careful measurement and by comparison with a spectrum in which the line was known to be absent. Several doubtful lines were measured with a traveling micrometer.

The results of the analysis appear in the accompanying table. Several elements, in particular, were sought, because they have been reported in similar minerals, but were not detected: aluminum, cadmium, cerium, cesium, gallium, indium, lithium, platinum, thallium, and yttrium. Although calcium and magnesium were found in the spectra of every sample, their presence may have been due entirely to atmospheric dust. Several elements that were absent in the spark were revealed in the arc spectra; the arc is usually more sensitive than the spark. Nevertheless, arsenic and

---

[2] Eder, J. M., and Valenta, E., Atlas Typischer Spektren: Wien, **1924.**

[3] Twyman, F., and Smith, D. M., Wave-length Tables for Spectrum Analysis: Adam Hilger Ltd., **1931.**

Kayser, H. G. J., Tabelle der Hauptlinien der Linienspektren aller Elemente: Springer, **1926.**

TABLE OF MINERALS, THEIR LOCATIONS, AND ANALYSES

Mineral	Location	Ag	As	Au	Bi	Ca	Co	Cr	Cu	Fe	Ir	Mg	Mn	Mo	Ni	Pb	Pd	Sb	Sn	Sr	Ti	V	W	Zn	Zr
1. Pyrite	Near Philipsburg, Mont.			x		x			x	x		x		x		x	x		x		x	x	x		
2. Pyrite	Elba.			x	x	x	x		x	x		x				x			x		x		x		
3. Pyrite	French Creek, Pa.				x	x	x		x	x		x		x	x	x			x				x		x
4. Pyrite	Commercial Mine, Bingham Canyon, Utah.			x	x	x	x		x	x		x		x		x	x		x			x	x		
5. Pyrite	Central City, Colo.			x	x	x	x		x	x		x		x		x			x		x		x		x
6. Sphalerite	Wheatley Mine, Phoenixville, Pa.	x				x			x	x		x				x	x				x			x	
7. Sphalerite	Kisbanya, Ungarn.				x	x			x	x		x	x			x		x	x				x	x	
8. Sphalerite	Oradna, Siebenburgen.					x	x		x	x		x	x			x							x	x	
9. Sphalerite	Lautenthal, Harz.	x			x	x	x		x	x		x	x			x			x					x	
10. Sphalerite	Warren, N. H.	x	x			x	x		x	x		x	x			x			x					x	
11. Sphalerite	Joplin, Mo.	x	x			x	x		x	x		x				x	x		x					x	
12. Galena	Leadville, Colo.	x				x		x	x	x		x	x			x	x		x	x		x	x	x	
13. Galena	Utah Apex Mine, Bingham Canyon, Utah	x				x		x	x	x		x	x			x	x		x	x		x		x	
14. Galena	Przibram, Bohemia.	x				x		x	x	x		x	x	x		x	x		x			x		x	
15. Galena	Bleiberg, Karnten.	x				x		x	x	x	x	x	x			x	x	x	x			x	x	x	
16. Galena	Joplin, Mo.	x				x		x	x	x	x	x				x		x	x					x	

antimony, elements not easily excited, were found only in spark spectra.

The author, in concluding, wishes to acknowledge the helpful suggestions of Dr. G. R. Harrison and Dr. W. H. Newhouse.

NOTES AND NEWS

A ROCK SAW

John W. Vanderwilt,* *U. S. Geological Survey.*

Many laboratories are equipped with either a diamond saw or a thin carborundum wheel for cutting small specimens of minerals or rocks but very few are equipped to cut specimens 3 inches or more across. Believing that this subject may be of interest to mineralogists and petrologists I shall describe an inexpensive and mechanically simple rock saw adapted from the "gang saw" used extensively in the marble industry. In the field office, of the Section of Metalliferous Deposits of the U. S. Geological Survey, at Golden, Colorado, this saw has proved itself very useful for cutting both large and small specimens.

The following does not imply that the power bandsaw used in larger laboratories is not an effecitve tool for sawing rock. The fundamental principle, that is the use of loose abrasive and a moving smooth blade of metal, is similar to that of the "gang saw" and even the hardest kind of rock can be cut. Undesirable features of a power band saw are that its cost is too high for many small laboratories, readjustment of specimen against saw blade is necessary every half hour or so, and that it scatters abrasives about the room. None of these objections can be made against the saw described.

Cutting with a "gang saw" is effected by loose abrasive dragged back and forth across a rock under the edges of a series of soft metal blades with the motion of a hack saw or hand wood-saw. In a single operation a "gang saw" cuts blocks of marble several feet across into a series of slabs. For our purposes only a single cut is necessary and therefore only a single metal blade is used, otherwise the operation is essentially the same. The principle employed is quite simple and can be applied in a number of mechanical ways. The particular set-up which I used is described in some detail in order to bring out the results obtained as well as the difficulties encountered. The mechanical arrangement can be made more elaborate or simple to suit one's desires for convenience of operation and expense of construction.

---

* Published by permission of the Director, U. S. Geol. Survey.

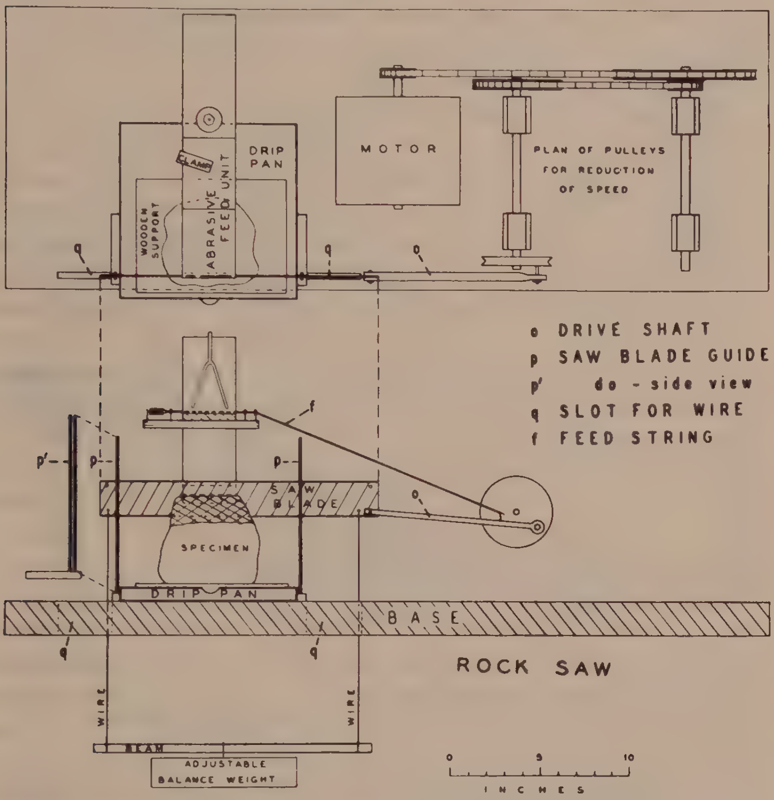

FIG. 1. *Above:*—Ground plan of motor, pulleys, shaft for driving saw blade, and position of specimen. *Below:*—Side view showing position of saw blade held in guides with respect to specimen, and the unit above the saw blade for feeding the abrasive.

The arrangement of the various parts of the saw is shown in figure 1 drawn approximately to scale. The plan and dimensions shown can readily cut specimens of any size up to 7 inches across and 5 inches high. It is evident that by enlarging certain obvious parts of the machine specimens of a larger size can be cut.

The saw blade moves with a horizontal 3 inch stroke at the rate of 100 to 150 per minute and is driven by a $\frac{1}{4}$ h.p. motor. The relatively low speed was chosen because with it, if anything should go wrong, less damage would occur and there would be no tendency for the abrasive to be scattered about the room. It is also believed that a slow rate of cutting is offset by the corresponding small amount of personal attention that is required. Experimental work was not done with different speeds or lengths of strokes. The approximate rates for making saw-cuts 7 inches long does not seem to be materially greater than for cuts 2 or 3 inches shorter. The approximate speed of cutting is:

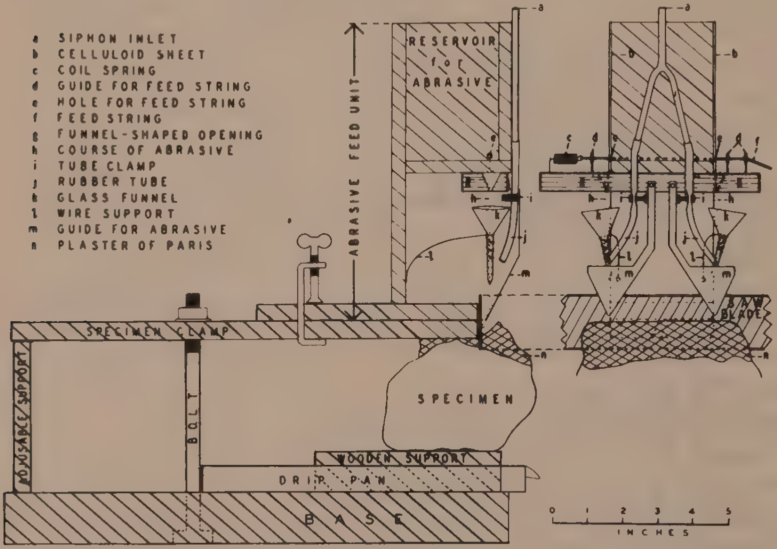

FIG. 2. Front view—*right*—and side view—*left*—of feed unit for abrasive and water showing its position with respect to the specimen, specimen clamp, and saw blade. The continuation of the feed string *f* is shown in fig. 1.

	Per Hour
Silicified wood and beryl	$\frac{1}{4}$ inch
Basalt and granite	$\frac{1}{2}$
Calcite and fluorite	1
Sandstone	1 to 2
Sulphide ores (depending on gangue)	$\frac{1}{2}$ to 1

Since the saw will operate all day with little or no attention these rates of cutting are considered very satisfactory.

The saw blade is a strip of 16 gauge sheet iron, 17 inches long and cut about 2 inches wide to give it stiffness. After one side of the blade has worn enough to cause the blade to ride unevenly, it can be turned and the other side used. The saw blade must be straight and it is essential to hold it in line with guides. Each guide is made with two ¼ inch rods, spaced the width of the blade, and set in a metal stand which is bolted to the base. The connecting rod is a stick of wood with a slot at one end in which the saw blade is held by a small bolt, and the other end of the connecting rod is attached to an eccentric fitted with a small ball bearing (from an old generator of an automobile). The connecting rod must move in line with the saw blade and, if the bearing does not hold it so, it will be necessary to add guides for this purpose.

Some pressure on the saw blade is necessary for effective cutting. This is obtained by means of a weight (2 to 5 lbs.) suspended from a beam held by wires attached to each end of the saw blade (see fig. 1). The weight is shifted to a position that will cause the saw blade to cut down evenly and to maintain it in an approximately horizontal position or one sloping slightly away from the eccentric; otherwise the blade will begin to ride unevenly and eventually stick. This adjustment of the weight ordinarily requires a little attention at the beginning of a "cut" before the saw blade has had time to seat itself. The difficulty in starting the "cut" can be overcome if, instead of using weights to hold the saw blade, it is held in tension by means of a coil spring attached to a standard (spring and standard not shown in diagram) at the end of the saw opposite the connecting rod. A rigid frame could no doubt be devised to apply pressure to the saw in a manner similar to that of a power hacksaw which would require little or no personal attention.

Number 80 mesh carborundum is used. As stated in the opening paragraph cutting is effected by an abrasive which is dragged across the rock under the edge of the saw blade. In addition to the abrasive a small amount of water must be added which acts as a lubricant and also washes out the fine powder that forms during the cutting of a rock. Cutting is most efficient when the abrasive and water are added at a controlled and even rate. This proved more difficult to accomplish and caused more trouble than any other feature connected with the saw. Too much abrasive and too little water permit the abrasive and rock powder to pack and clog under the saw blade with an inevitable decrease in the rate of cutting. Similarly an excess of water, since it tends to flush the abrasive out too fast, retards the rate of cutting. After a certain amount of experimenting, a feed unit was developed as shown in figure 2. It is not as complicated as it may appear in the diagram. The unit is fastened to the clamp holding the specimen in order that its relative position to large or small specimens may be the same. The sides of the reservoir for the abrasive are sheets of celluloid about 2 mm. thick. A string about 1 mm. in diameter is passed through two holes (*e* hole for feed string--size exaggerated in the diagram) opposite each other and through the celluloid. The holes are slightly larger than the string and as the string is pulled through them abrasives will be dragged out. One end of the string is fastened to the connecting rod (fig. 1) which at each stroke pulls the string in one direction. The other end of the string is attached to a small coil spring, fig. 2, which returns the string after each pull given by the shaft. The to-and-fro motion of the string pulls abrasive through the holes first from one side and then from the other. Guides (*d*) are necessary to hold the string in line in order to prevent the holes in the celluloid from being enlarged by wear. The abrasive passes through the funnel-shaped opening and glass funnels, falling on the guide for the abrasive. The glass funnels can be adjusted by means of their flexible wire supports and the guides of thin sheet iron can be bent to direct the abrasive where it may be needed. Water drips on the guide and washes the abrasive onto the saw blade. The amount of abrasive used is regulated by adjusting the length of the feed string, and the flow of water (generally a slow drip) is controlled by means of the clamps on the rubber tube.

The position of the specimen and the manner in which it is clamped in place is shown in fig. 2. The clamp is a soft board held by a bolt. It is necessary to have the clamp nearly horizontal since the feed unit rests on it, and this can be readily done by matching the adjustable support to the height of the specimen. A drip pan or some means to confine the water and abrasive is necessary for cleanliness and a pan fitted with a lip to drain off the overflow was found to be very convenient.

The saw blade wears most directly over the center of the specimen and for this reason it is necessary to have a wooden support to hold the specimen well up in order that the edges of the drip pan may remain clear of the saw blade. In fig. 2, plaster of Paris as shown is not always essential but is convenient for making a drain to direct the abrasive and water towards the saw blade. Without such a drain the abrasive is just as apt to spread away from as to move under the edge of the blade. Plaster of Paris is also very convenient to fix a specimen of irregular and uneven shape in a desired position. It is also very satisfactory for mounting several small specimens so they can all be cut in one operation.

The cost of the equipment used for the saw amounted to about \$17.50 which includes: a $\frac{1}{4}$ h.p. reconditioned motor, \$6.00; 2 power bench-grinder shafts, \$5.50; and the V-pulleys with belts, \$3.50. All these items can be ordered from mail order houses or establishments dealing in machine shop supplies. The drip pan and guides for the saw blade, made to order in a tin shop, cost \$2.50. The saw blades of 14 to 16 gauge sheet iron cost 4 to 6 cents each. Several other small items used are odds and ends that were available in the laboratory and their cost if they had to be purchased would add relatively little to the expense. The time required to assemble the saw if calculated as hired labor would add materially to the cost of the machine. The expense of operation is not great. With proper adjustment about one pound of abrasive and about 5 kilowatts of electricity are used during a 10 hour period, which brings the cost to about 5 cents per hour. It is practical to wash and clean the abrasive, thus reducing the cost of operation.

THE DUSTFALL OF NOVEMBER 13, 1933

A. E. Alexander, *Buffalo, New York.*

From the west on Monday, November 13, 1933, came strong westerly winds laden with dust which covered the city of Buffalo with a noticeable coating of grit. Fortunately, the city at the time was covered with several inches of snow. The writer collected a shovelful, taking only the top few inches so as to avoid possible contamination. The snow was melted, the resulting liquid filtered, and the residue dried. This was mounted in Canada balsam. Examination under polarized light showed that the grit was composed of mineral and organic matter, the following being identified:
1. Volcanic ash; 2. Quartz; 3. Feldspars (orthoclase, microcline, plagioclase); 4. Hornblende; 5. Tourmaline; 6. Zircon; 7. Mica; 8. Diatom tests; 9. Spores and pollen grains; 10. Plant hairs.

The dust particles varied in size from .005 to .5 mm.; the average of 80% of the whole sample examined being somewhat less than .02 mm. in size. While most of the particles were angular to subangular, several very tiny grains, too small to identify positively, but birefringent under crossed nicols, were distinctly rounded or subrounded. Since they showed abnormal blue interference colors, they may have been zoisite or vesuvianite.

The volcanic glass, in transmitted light showed the presence of two varieties. One colorless, containing inclusions which may have been either liquid or gaseous, and a black variety, suggestive of basaltic glass. The hornblende was light green in color, faintly pleochroic, and possessing well defined prismatic cleavage. Several euhedral grains of tourmaline were seen. The pleochroism of this mineral varied. In some grains it was brown and in others, blue. All the zircon crystals possessed prismatic and pyramidal faces and were colorless. The few flakes of mica present were, for the most part, muscovite, although several green flakes were seen, suggesting some variety of biotite. The feldspars were unaltered and were angular to subangular in appearance.

The quantity of organic matter present in the sample was large, estimated at 10–20% of the entire mass. About a dozen different species of diatom tests were identified. The spores and pollen grains varied in form and number. Some were smooth, others irregular, rough, or spinous. They possessed a variety of shapes, ranging from spheres to oblong and ovate bodies. Mrs. Imogene Robertson, assistant curator of biology, at the Buffalo Museum of Science, kindly differentiated the organic matter for the writer.

It is interesting to note in this connection, that Winchell and Miller,[1] in a study of the dust particles of the dustfall which occurred over Wisconsin in 1918—found that the material consisted mainly of unaltered feldspar, quartz, minor amounts of accessory minerals, and some organic matter. Tests of diatoms were also recorded. Twenhofel[2] suggested that the place of origin of this dust was the semi-arid region of New Mexico, Arizona, and adjacent states. The assemblage of organic and inorganic matter found in the Buffalo grit is likewise characteristic for the most part of dried up playa lakes, ponds, or floodplain areas.

As to the probable source of this material, a consideration of the weather maps was deemed advisable. Mr. J. Patterson, meteorologist for the Toronto Weather Bureau, kindly forwarded complete weather data showing the place of origin of the storm and the trend that it subsequently followed. The low pressure area originated in Alaska, moved southeastward to British Columbia, and then turned east, the center of the low pressure area keeping to the north of the International boundary. Dust however, was reported as far south as the Carolinas on the same day that it fell in Buffalo, New York.

An article in the New York Times, Jan. 7, 1934; states that a dustfall occurred at Montreal on Dec. 17, 1933. Geologists at McGill University considered the dust to be a volcanic ash, consisting mainly of quartz, feldspar, and mica.

The writer believes that the Buffalo dust originated in Alaska, to account for the presence of volcanic glass. However, as the storm progressed across Canada and the United States; large quantities of grit were picked up, as in the Dakotas for example, and added to that derived from the far north. The dust that fell in western New York State therefore probably represents a mixture of materials derived from widely scattered sources in the west and northwest.[3]

---

[1] Winchell, A. N., and Miller, E., The Dustfall of March 9, 1918: *Am. Jour. Sci.*, vol. **46,** pp. 600–603, 1918.

[2] Twenhofel, W. H., *Treatise on Sedimentation:* Williams and Wilkins Co., p. 68, **1932.**

[3] Watson, E. H., Note on the Dust Storm of November 13, 1933: *Science*, vol. **79,** No. 2049, p. 320, 1934.

BOOK REVIEW

THIN-SECTION MINERALOGY. Austin F. Rogers and Paul F. Kerr. Pp. 311+XI, figs. 261. McGraw-Hill Book Co., Inc., New York and London, **1933.** Price $3.00.

This small inexpensive book covers the field of thin section mineralogy in a remarkably satisfactory way. The chapter on the preparation of thin sections takes up only five pages but it includes all the essentials. The longer chapter on the polarizing microscope describes the various microscopes and accessories and gives a good section on the adjustment of the microscope.

The next chapter on the properties of light gives an excellent brief statement of the development of the theories of the transmission of light. Some slight errors have crept in. On page 34 figures *b* and *c* should be interchanged.

The chapter on refraction describes the methods of measuring indices of refraction by the refractometer, by prisms and by the immersion method. The authors explain the method of central illumination only for vertical contacts (after Hotchkiss) and do not explain the lens effect, which is no doubt much more important. The chapters on plane and convergent polarized light are brief but excellent. On page 105 under figure 87 the dispersion should be $r>v$.

In the chapter on color, form of aggregation, cleavage, and orientation, the discussion of form and cleavage is espcially good and excellently illustrated by text-figures. Twenty pages are given to tables.

About half the book is devoted to descriptions of individual minerals. The descriptions are condensed and follow a uniform arrangement. At the head are given the composition, crystal system, and tabulation of the chief optical properties; then under the headings, color, form, cleavage, relief, birefringence, extinction, orientation, interference figure, distinguishing features, and occurrence, brief but excellent descriptions are given. One wonders whether some of these sections are necessary. For instance, on page 265 after the indices of refraction, axial angle, optical character, and orientation for piedmontite have been given, the later statements are made "Relief high, $n>$balsam," "Birefringence very strong to extreme, $n_\gamma-n_\alpha=0.061$," "Interference Figure.— The figure is biaxial positive with large axial angle. The axial plane is $\{010\}$." Are these latter statements needed? The space saved might profitably be used for other data.

In some of the mineral groups the gradational character of the members and the complications of the groups are not brought out. For instance, the amphiboles are treated as if made up of a small number of distinct species, anthophyllite, tremolite, hornblende, basaltic hornblende, riebeckite, and glaucophane.

The book is well balanced. The early chapters on methods and theory are brief and elementary, but they avoid the "cook-book methods" so objectionable in some textbooks. The numerous text-figures are especially well chosen and executed. The wide practical experience of the authors in microscopic work and in teaching has helped to make this the best elementary book in its field. It should be a widely used text- and hand-book.

Esper S. Larsen

PROCEEDINGS OF SOCIETIES

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND

MINERALOGICAL SOCIETY, *January 25*. SIR THOMAS H. HOLLAND, President in the chair.

PROFESSOR C. E. TILLEY exhibited specimens and sections of a new mineral hydrocalumite from Scawt Hill, County Antrim, Northern Ireland, and MR. A. T. DOLLAR exhibited bent and twisted quartz crystals from Lundy Island, Devonshire.

DR. JAMES PHEMISTER: *Zoning in plagioclase feldspar*. The paper describes various types of zoning in plagioclase feldspar in the calciferous sandstone basalt lavas in one district of Scotland. The zoning is classified as (a) normal, (b) simple reverse, (c) oscillatory. Simple reverse zoning is associated with other differences in the zones which point to important time intervals between the growth of the zones. Oscillatory zoning is classified as oscillatory-normal and oscillatory-reverse and attention is drawn to the occurrence of oscillatory-zoned crystals which show no general tendency towards either more calcic or more sodic plagioclase. Distinction is drawn between the main zones and the thin shells of alternately more and less calcic composition within the main zones. The alternating composition of the thin shells is possibly the result of lack of balance between rate of growth of the crystal and rate of diffusion from the surrounding magma. Recurrence of calcic plagioclase in the inner part of main zones is explained as the result of eruption of hot magma into the crystallizing liquid, probably consequent on eruption of lava at higher levels.

PROF. H. H. READ: *On zoned associations of antigorite, talc, actinolite, chlorite, and biotite in Unst, Shetland Islands.* In an injection-zone within the staurolite-kyanite-garnet-gneisses of western Unst occur spherical or ellipsoidal bodies, up to 20-ft. diameter, composed of an interior of antigorite, followed outwards by an orderly sequence of zones made up entirely of talc, of actinolite, of chlorite, and of biotite. It is considered that the zoned bodies result from the fragmentation of peridotite sills during the staurolite-kyanite-garnet metamorphism, followed by the entry of fluids into the masses during injection-metamorphism and the formation of the zonally arranged layers. At the same time material displaced from the masses reacted with the country-rock to give the biotite-zone. Transitions to the country-rock were mostly pared away during the later chloritoid- and chlorite-producing metamorphisms that have affected the staurolite-kyanite-garnet-gneisses.

MR. M. H. HEY and MR. F. A. BANNISTER: *Studies on the zeolites. Part VII.* Clinoptilolite, a silica-rich variety of heulandite. Rotation photographs of a single crystal from the original specimen of "clinoptilolite" (so-called "crystallized mordenite" of L. V. Pirsson) show that it is a silica-rich variety of heulandite. The chemical composition and optical properties are in agreement with this interpretation. The mineral bears no relation to ptilolite.

MR. B. RAMO RAO and DR. A. BRAMMALL: *Notes on cordierite in the Dartmoor granite.* Two groups of associated but as yet unrelated facts were recorded concerning the sector-twinned cordierite in the garnetiferous granite of Swelter: (1) an aggregate of cordierite grains is separable into fractions varying in composition; in particular, the molecular ratio FeO/MgO varies from 0.37 to 1.28 in six intermediate fractions analysed, the ratio for the aggregate being 1.52. (2) All sectors are optically negative, but the value of 2V varies between 56° and 72°. Centrally paired sectors give the same 2V value, whereas adjacent sectors often give different values the maximum difference observed being 12°.

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, February 1, 1934

President Gillson presided at a stated meeting, with 41 members and 13 visitors present. The proposed amendment to Article II, section 3 of the By-laws was rejected.

Professor J. E. Shrader of Drexel Institute, Philadelphia, spoke on "Polarized Light," and demonstrated his lecture by means of a projection apparatus which he had constructed. Dr. Gillson outlined the "Use of Polarized Light and the Petrographic Microscope in Mineral Identification."

Mr. H. E. MacNelly exhibited a polarizing microscope which he had constructed at little cost, using pieces of black glass to polarize the light. Mr. Teubner described his use of telescope lenses in a camera attachment for making photomicrographs.

Mr. Charles R. Toothaker showed some lantern slides of unusual Guanajuato calcites.

W. H. Flack, *Secretary*

NEW YORK MINERALOGICAL CLUB

Minutes of the Meeting of February 15th, 1933

A regular meeting of the New York Mineralogical Club was held at The American Museum of Natural History on the evening of February 15th, 1933 with an attendance of 87. The meeting was called to order by 1st Vice-President George E Ashby.

Dr. Laurence F. Rainsford of Rye, N.Y., Mr. Frederick Schneider of Woodhaven, L.I., and Mr. Herbert S. Zim of New York City were elected to active membership.

President Alfred C. Hawkins introduced the speaker of the evening, Dr. Clarence S. Ross of the United States Geological Survey, Washington D.C., who lectured on "The Minerals and Mineral Relations of the Nelson County, Virginia, Titanium Locality." Dr. Ross described the titanium deposits of Virginia as occurring in the Piedmont section of the state, between Charlottesville and Lynchburg, in an area, roughly elliptical, 17 miles long and 3½ miles in the widest place. He pointed out that there are two types of occurrences—one, disseminated in a feldspathic rock of pegmatitic habit, and the other as "nelsonite," a rock composed essentially of rutile or ilmenite and apatite. The feldspathic rock has been profoundly fractured, recrystallized, and locally replaced by narrow, roughly parallel lenses of a ferromagnesian rock. The titanium minerals have been introduced along with this ferromagnesian rock as the hydrothermal solutions migrated outward replacing the feldspar. Ilmenite has formed closest to the ferromagnesian rock and rutile at a greater distance. Although the mode of origin of all the nelsonite bodies is uncertain, it is believed some have been formed in the same manner as the lenses in the feldspathic rock; i.e., through replacement by hydrothermal solutions. Blue quartz, which is abundant in the area, owes its color to minute needles of rutile 0.3 to 0.4 microns in diameter. The lecture was illustrated with lantern slides. Dr. Ross was enthusiastically thanked by President Hawkins on behalf of the Club for his very interesting lecture. The discussion which followed led from the blue quartz discussed by Dr. Ross to rose quartz and the probable cause of its color; it was explained as due to manganese in colloidal form. Mr. H. R. Lee mentioned that a rose quartz had been produced by heating pieces of quartz in a nickel crucible.

Following the lecture the meeting was again opened for business. Mr. Gilman S. Stanton reported for the committee empowered to purchase certain minerals at the January meeting and revealed that they had secured for the Club Collection two famous specimens of chrysoberyl from New York City, formerly in the collection of the late Wallace Goold Levison. When Dr. Levison died in 1924, his family refused to part with the specimens, but they were finally obtained from his nephew.

In response to the letter from Professor Edward Salisbury Dana of Yale University soliciting aid for the needy mineralogists abroad, a motion was made by Dr. Paul F. Kerr and seconded by Mr. James F. Morton that the Club again send twenty-five dollars to Professor Dana for this worthy purpose, and it was so ordered.

DANIEL T. O'CONNELL, *Secretary*

NEW MINERAL NAMES

Cuprosklodowskite

J. P. VAES: Sur un Minéral de Kalongwe (Katanga), *Ann. Soc. Geol. Belg.*, Bull. 10, vol. 56, pp. 331–2, 1933. H. BUTTGENBACH: Communications, *ibid.*

NAME: From its analogy to sklodowskite.

CHEMICAL PROPERTIES: A hydrous silicate of copper and uranium.

CRYSTALLOGRAPHICAL PROPERTIES: Orthorhombic. Habit acicular. Forms: (110), (100), rarely (010); frequently terminated by (*okl*), probably (031). $110 \wedge 031$ about 69°–72°.

PHYSICAL AND OPTICAL PROPERTIES: Color greenish yellow. Pleochroism greenish yellow parallel to elongation, colorless normal to needles. The face *m* shows an eccentric emergence of an optic axis. Dispersion very strong $r > v$. $n = 1.68–1.70$.

OCCURRENCE: Found in small acicular needles in a fissure in a talcose argillaceous rock at the uranium occurrence at Kalongwe, Katanga.

W. F. FOSHAG

Uranolepidite

J. THOREAU: L'uranolépidite, Nouveau Minéral uranifere de Shinkolobwe (Katanga), *Ann. Soc. Geol. Belg., Publ. spéc. relat. Congo Belge.*, 1931–1932. pp. C3–C5, 1933.

CHEMICAL PROPERTIES: A hydrous copper uranate, $CuO \cdot UO_3 \cdot 2H_2O$. Analysis (by W. Boubnoff), CuO 18.98, CaO 0.26, MgO 0.57, UO_3 70.40, SiO_2 0.28, CO_2 None, H_2O (580°) 9.46; Sum 99.95.

PHYSICAL AND OPTICAL PROPERTIES: Color deep green. Pleochroism deep bluish green to paler yellowish green. Three cleavages, parallel to needles, perfect; normal to first, distinct; oblique, traces. Biaxial, negative, 2V large. Dispersion strong. Plates parallel to first cleavage show $z \wedge$ elongation about 40°. Parallel to second cleavage sensibly perpendicular to an optic axis. $\alpha=1.79$; $\gamma=1.80 \cdot G=5.03$. Hd. between 3 and 4.

Occurrence: Found in lamellar masses of deep green color associated with a black cobalt mineral on a specimen composed principally of curite and uranophane.

(Uranolepidite from Chinkolobwe and vandenbrandeite from Kalongwe, discovered nearly simultaneously, are identical. Priv. com. J. Thoreau to abstr.)

W. F. F.

Thoreaulite

H. Buttgenbach: La Thoreaulite, Nouvelle espéce minérale. (Note préliminaire). (Thoreaulite, a new mineral species). *Ann. Soc. Geol. Belg.*, vol. **56**, Bull. 10, pp. 327–328, 1933.

Name: In honor of Prof. J. Thoreau, who has published works on the ore and rock occurrences of the Belgian Congo.

Chemical Composition: A stanno-tantalate, probably $Ta_2O_5 \cdot SnO_2$. Partial analyses (by Melon and by Christoe), Ta_2O_5 72 and 74%, SnO_2 20 and 22%. Spectrographic examination shows the presence of antimony and lead and traces of titanium, zinc, nickel, thallium and magnesium.

Crystallographical Properties: Monoclinic?

Physical and Optical Properties: Color brown, passing to red upon alteration. Streak brown, slightly greenish. Cleavage, very good. Luster on cleavage, resinous or adamantine. The thin cleavages are yellow, not pleochroic. $n>1.74$. Birefringence very high.

Occurrence: Found in a pegmatite at Manono, Katanga.

W. F. F.